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PLATE I.

THE ROYAL ASTRONOMICAL SOCIETY GOLD MEDAL AWARDED TO PROFESSOR BARNARD, 1897.

Popular Astronomy.

Vol. V. No. 1. MAY, 1897. Whole No. 41.

ADDRESS OF THE PRESIDENT OF THE ROYAL ASTRONOMICAL SOCIETY.

Your Council have this year awarded the Gold Medal of the Society to Professor Edward Emerson Barnard, for his discovery of the fifth satellite of Jupiter, his celestial photographs and other astronomical works, and, according to custom, it becomes my pleasant duty to state more fully the circumstances that have influenced the Council in making this award.

The discovery of the fifth satellite of Jupiter (certainly the most important discovery of the last twenty years) is the product of three factors—a good telescope, a good sky, and a good observer. To the munificence of James Lick the telescope on Mount Hamilton is due, and without detracting in the slightest degree from the credit that is due to Professor Barnard for his magnificent discovery, a large share of honor remains to James Lick and the maker of the telescope, George Alvan Clark.* Without this particular combination of men it is not too much to say that the fifth satellite would yet remain to be discovered. We may congratulate our medallist on having the opportunity of using the Lick telescope, and we may certainly also congratulate the donor and the maker on having secured an observer like Professor Barnard to do justice to the telescope. Though since its discovery it has been seen by other observers in America and a few in England, yet, as was pointed out by Sir John Herschel, the difference between seeing an object already known to be there and discovering that object is very great, and, moreover, although the satellite has been seen by others, with the exception of Hermann Struve at Pulkowa, they have been unable to measure its position. Our knowledge of its orbit is due almost entirely to the observations of Professor Barnard himself. I do not know that I can demonstrate the magnitude of

NOTE.—Delivered by the President, A. A. Common, L.L. D., F. R. S., on presenting the Gold Medal to Professor E. E. Barnard.

Before proceeding with his address the President expressed his deep regret that Professor Barnard was not present at the meeting. He had left New York on February 2 in order to be present on this occasion, but his ship, the Trave, had not yet arrived, and the fact that other Atlantic liners were overdue made it probable that there had been some rough weather causing the delay. As events proved, this surmise was correct, the Trave reaching Southampton after midnight the same night, February 12.

* Alvan G. Clark is undoubtedly meant.

Professor Barnard's especial achievement more clearly than by calling to mind that his friend, Professor S. W. Burnham, our medallist of three years ago, had shared with him the advantages of telescope and climate for some years, and yet the satellite remained unknown.

To us the news of the discovery was announced from Mount Hamilton in the following telegram: "Professor Holden announces that the Lick telescope has revealed the existence of a fifth satellite to Jupiter with a period of $12^h\ 36^m$. Its distance from the centre of the planet is 112,400 miles, and its light compares with that of a star of the thirteenth magnitude," published on 1892, September 13, (the satellite having been discovered on September 9), which was followed by a later telegram informing us that Professor Barnard had made the discovery, and placing the period at $17^h\ 36^m$. The confusion that arose from these telegrams was not cleared up till about October 16, by the receipt of the *Astronomical Journal* of October 4, No. 275, in which Professor Barnard gives an interesting account of his discovery of this satellite, with the measurements he had made.

From the elongations he deduced a period of $11^h\ 49^m.63$, but as this was only from measurements obtained between September 9 and 14, it was, of course, only a first, but, considering the extreme difficulty of the object, a very close approximation. Later observations made by Professor Barnard have enabled the period to be better determined at $11^h\ 57^m\ 22^s.60$.

He has given a most interesting account of his discovery and a diagram showing the relative size of the satellite as compared with the other four. He estimates the diameter at about the $\frac{1}{900}$th part of the diameter of Jupiter, and states that a magnification which raised the other four satellites to veritable moons failed to increase the diameter of the fifth. This little body stands quite by itself in the Jovian system. In the recently published volume iv. of his *Mécanique Céleste* our late lamented Associate, M. Tisserand, remarks that the theory of its motion must be discussed quite apart from those of the other four, whose movements it is probably too small to influence seriously. Had it been larger, and our knowledge of the motions of the other four more completely worked out, it is conceivable that we might have got some suspicion of its presence from theoretical considerations, but it is noteworthy that neither in this way nor in any other was the actual discovery led up to. In the case of Hyperion there was a marked gap in the already complex

Saturnian system which suggested the possibility of another satellite, but we had become so thoroughly accustomed to the well-established Jovian system that it must have required a positive effort to conceive the possibility of an addition to it, and in this way I regard the discovery of Professor Barnard as most remarkable.

I have alluded to the discovery of Hyperion; and, in fact, our minds, on such an occasion as the present, naturally turn to others of the same character.

Besides the fifth satellite of Jupiter, our century has produced six new satellites, of which four belong to those red-letter years 1846 and 1847, which added to the solar system Neptune and his satellite, two new satellites of Uranus and one (Hyperion) of Saturn. William Lassell, who had the whole credit of two of these discoveries, and a share in that of the others, received our medal in 1849 from the hands of Sir John Herschel "for the construction of his equatorial instrument and the discoveries made with it." The prominence given to the construction of the instrument bears out what I have already ventured to say above. In his presidential address, Sir John Herschel quoted an official report to the following effect: "The simple facts are that Mr. Lassell cast his own mirror, polished it by machinery of his own contrivance, mounted it equatorially in his own fashion, and placed it in an Observatory of his own engineering; that with this instrument he, a private man, of no large means, in a bad climate, discovered the satellite of Neptune, the eighth satellite of Saturn, and re-observed the satellites of Uranus."

Thirty years elapsed before any more new satellites were brought to our knowledge, and then Professor Asaph Hall (aided by the same constructive skill as that which enabled our present medallist to make his brilliant discovery, that of the Alvan Clarks), announced the two satellites of Mars. In 1879 he received our Medal for this great achievement from the hands of Lord Lindsay, now Lord Crawford. It is by the side of these men—one an Englishman, of whom we are justly proud, and the other a fellow countryman of his own, in whom he doubtless has a similar national pride—that Professor Barnard now takes his place; and, in recognition of his right to this place your Council has conferred upon him the highest honor in its power. Although the number of satellite discoveries credited to these three men shows a progressive decrease from four to two and from two to one (a minimum which it is, however, impossible to further reduce in the future), the quality of the achievement

must on the other hand progressively rise; for it may be confidently asserted that each new discovery is harder than those preceding it. Moreover, our present medallist has other claims of an equally high character on the respect and admiration of astronomers. The terms of the formal award include his photographs and other astronomical work. But before passing to these I will venture to follow the example set by Lord Lindsay on the occasion to which I have already referred, in giving some account of the life of the man whom we hoped to have seen among us today. Lord Lindsay remarked that Mr. Asaph Hall's early history afforded "a bright example of what perseverance and determination may effect in overcoming even the most adverse circumstances," and this is equally true of our present metallist. Indeed, when we consider the life-histories of astronomers who have become famous, we cannot but be struck with their general similarity. In so many cases they have become astronomers, not through the action of outside forces, but very often in spite of them, and simply from their own determination. Professor Barnard's early life, as described* by his friend, S. W. Burnam, is like that of many other notable astronmers, but with every turn accentuated to a degree almost romantic.

He was born at Nashville, Tennessee, in 1857. His early education was limited to two months' attendance at a common school, and such instruction as his excellent mother could give him at home. Fatherless and destitute at the close of the war, he began at the age of eight or nine to work in a large photographic studio in Nashville, and soon became a faithful and accomplished assistant to his employers. The loan by a friend of Dr. Dick's book, the *Practical Astronomer*, in 1876, awakened a love for astronomy which soon grew into a passion. The use of a 1-inch cheap lens roughly mounted in a tube of his own construction showed him something of what a telescope would do; and the visit of a travelling showman to Nashville, with a small glass for street exhibition, further stimulated him to acquire as good an instrument as he could for himself. Accordingly, by practicing the most rigid economy he was enabled in 1877 to purchase a 5-inch telescope, and it is significant that his first systematic work of any importance was a careful study of the planet Jupiter. In 1881 he began to search for new comets with his 5-inch, and discovered one on September 17 of that year. This was followed a year after by another, and in 1884 he found a comet of period 5.4 years. The next year, 1885,

* Popular Astronomy and Harpers Magazine, September, 1893.

yielded two new comets, 1886 one, and 1887 three more; and in the five succeeding years he found altogether eleven comets, one them (1892 V) being another new comet of short period (6.30 years). One notable result of this success was that he several times obtained the prize of 200 dollars offered by Mr. Warner for the discovery of a new comet, and was thus enabled to buy books and other accessories and to pursue his studies with fewer financial anxieties.

In 1883 he left the photographic business, having received a Fellowship in Astronomy at the Vanderbilt University. During the preceding years he had given all his spare time to study, working in the daytime and studying alone at night. It is easy to mention these facts in a few words, but not so easy to give an idea of all that they mean—the continuous and courageous struggle against adverse circumstances of all kinds. He now utilized to the full the opportunities afforded by the University in the time he spared from the hard work at the 6-inch equatorial, which resulted in the cometary discoveries above mentioned, and in many others, such as new nebulæ and double stars. To one of these last I shall refer presently.

In 1888 he was offered a position in the Lick Observatory, then about to be opened with the largest equatorial in the world, in a climate of which Professor Barnard is wont to speak with an almost reverent enthusiasm; and the able way in which he availed himself of these advantages is now familiar matter of history. With one notable exception (that of the Sun) every description of celestial object has come under his scrutiny, and his skill as an observer is only equalled by his skill as a photographer. And after thus briefly reviewing his career I now return to his work, and especially to his photographs, which are definitely mentioned in the terms of the award of the Medal.

The astronomical photographs which Professor Barnard has made are chiefly of comets and of the Milky Way, taken with the "Willard" lens of the Lick Observatory, having an aperture of 6-inches and a total length of 31-in. These latter are perhaps the finest examples of star photography extant. Moreover they are the *first photographs* made to show the structure of the Milky Way. Many observers have made eye investigations on the distribution of the stars in the Milky Way. Amongst others we may note those elaborate representations of the galaxy south of 12°.5, which became accessible in 1877 by the Atlas of the *Uranometria Argentina* of Dr. Gould and his assistants at Cordoba followed by the elaborate map which Dr. Boeddicker pre-

pared at Lord Rosse's Observatory. These, with the drawing by Mr. Trouvelot, and the earlier drawing made by Sir John Herschel at the Cape of Good Hope, represent the attempts made to delineate the Milky Way by the pencil, and anyone working at the distribution of stars in the Milky Way will naturally use these drawings for comparison.

Personally I have little doubt of the essential inferiority of the drawings to the photographs and, though it may be of some interest to know the points of difference, I cannot but think that photographs such as those of Professor Barnard are the only safe ground in such an investigation.

With regard to the comet photographs, our medallist has the credit of having made the first discovery of a comet by photography, an event which, of course, was bound to come sooner or later, but for which full credit may freely be granted to the first in the field. The series of photographs of comets taken by Professor Barnard, showing, as they do, the rapid changes that take place in comets' tails, are of great value. He has also actually obtained meteor trails on his photographic plates. Exposing plates on 1890, August 9, 10 and 11, he got traces of the trails of meteors, and on one of the plates of Brooks' Comet, taken on 1893, November 13, there is a very fine trail of a meteor. Finally with a small lens of short focus, Professor Barnard discovered the great nebula surrounding the belt of Orion.

We have in the library of this Society some sixty glass photographs presented by Professor Barnard, positive copies made with his own hands of some of his photographs. An inspection of these beautiful pictures, which are, I trust, well known to most of us, will reveal their merits far better than any description I can give, and I will offer but one further remark on the photographic work of our medallist. In the case of his discovery of the fifth satellite, we saw that there were at least three important factors, without any one of which success could not have been attained. But in the photography of our medallist, and in much of his other work, the external factors have less significance, and the results may be claimed almost entirely by the observer himself. Professor Barnard has shown us with what modest means good results can be obtained—with not only a small but a cheap lens, such as may be found in any magic lantern. No doubt his early experiences, of which I have spoken, were valuable in giving him this knowledge of what can be done with humble apparatus; but we must certainly admire,

not merely the skill, but the courage of a man who could, under the very shadow of the great 36-inch refractor, demonstrate the merits of a lens which could be bought for a few shillings.

Such a demonstration we might have naturally awaited from a man whose instrumental equipment was necessarily small, or who could not use a large telescope to advantage; that it should come from Professor Barnard, who had not only the opportunity of using the great refractor, but conspicuous ability for such work, is proof not only of his untiring industry, but of his thoroughly unprejudiced mind.

To summarise the other work of our medallist is a matter of some difficulty, owing to its enormous amount and its varied character. Up to the end of last year he had published twenty-six papers in the *Monthly Notices*, eighty-five in the *Astronomische Nachrichten*, seventy-five in the *Astronomical Journal*, and seventy-four in other American papers connected with astronomy, including an important report on the eclipse of 1889 January 1, published by the Lick Observatory. These represent, in nearly every case, work done at the telescope, and show him a brilliant and untiring observer of the very first order. I shall make no attempt at completeness, but shall merely endeavor to illustrate his extraordinary keenness in observing and his versatility; and as a first illustration, I will mention his independent discovery in 1883 of that singular phenomenon called the "Gegenschein." This was discovered many years ago by a German astronomer, though its cause is still a mystery, and even now but few astronomers, though they know what to look for, have ever seen it. That our medallist should have independently discovered it, having no knowledge of it previously, is testimony to observing skill of the highest quality; and the fact that he himself, as I understand, estimates the discovery as a piece of his very best work is in itself very significant. In the same year he accomplished a unique performance in double star astronomy. Noticing that the star β Capricorni disappeared at occultation by the Moon, not instantaneously, but gradually, he had sufficient confidence in his observation to ask for scrutiny of this star with the most powerful instruments available, and ultimately, with the 18½-inch equatorial of the Dearborn Observatory at Chicago, his friend S. W. Burnham found the star to be a close and unequal double, which, as Professor Burnham himself remarked, "taxed the powers of that splendid instrument to show even to a trained eye."

To the cometary discoveries of our medallist already mentioned, it must be added that in 1889 August he discovered four satellites

of Brooks' comet, and that he has followed faint comets long after they had become invisible in other instruments, notably Brooks' comet of 1889, which was observed by him nearly a year longer than by any other observer; and again, the comet discovered by himself in 1888, which he followed for over two years, the longest duration of visibility known. Such observations suggest the possibility of following some of the periodic comets all round their orbits, though it must be confessed that we are still far from the realization of this hope.

Again, he has classified periodical comets by their visual appearance, so that on several occasions he has been able to tell a short-period comet at the first glimpse in the telescope.

In addition to the photographic discovery of new nebulæ, he has discovered many with the telescope; he has made many observations of the surfaces of the planets Mars, Jupiter, Saturn, and of Jupiter's satellites (some of which are yet unpublished), particularly the very important one of the first satellite of Jupiter, showing the presence of dark polar caps and a white equatorial band, an observation of the utmost delicacy and importance, particularly in the light of the anomalous appearance attributed to this satellite.

Working with the 12-inch as well as the 36-inch telescope of the Lick Observatory, he has made a series of measurements of the diameters of the major planets and of their satellites, as well as of Mercury and Venus, and the first four asteroids and many measurements of Saturn's rings. His measurements of double stars are not yet all published, but they include re-measurements of many of Burnham's difficult doubles. In addition he has discovered many others, as for instance, the most delicate double star connected with the trapezium of Orion and β Capricorni, which I have already mentioned.

I trust that these instances, not exhaustive, but tolerably representative, will be sufficient to show that the claims of Professor Barnard to the honor now conferred upon him are both strong, diverse in character, and very numerous.

It would, indeed, be a thankless task to attempt a complete account of his work, for the completeness would certainly be lost in a very short time. Professor Barnard is in the presence of new opportunities which we all feel sure will add to his triumphs. He has left Mount Hamilton, but he has only exchanged one big telescope for another, and when the Yerkes refractor is ready, we may confidently expect news from Chicago of the kind with which he has made us familiar in the past.

PLATE II.

THE ARAGO GOLD MEDAL AWARDED TO PROFESSOR BARNARD, 1893.

PLATE III.

THE LALANDE GOLD MEDAL AWARDED TO PROFESSOR BARNARD, 1892.

The President then addressed the Foreign Secretary as follows:—Dr. Huggins:—I hope that it will not be necessary to ask you to forward this Medal to Professor Barnard, but that you will, within a very short time, be able to hand it to him. In doing so, I will ask you to express our great appreciation of his past work, and our very best wishes for his success in the future.

A SKETCH OF THEORETICAL ASTRONOMY.

ASAPH HALL.

For Popular Astronomy.

Theoretical astronomy has gained so secure a foundation, and its results are so generally accepted, that the trials and tribulations of astronomers on account of their opinions are matters of the past. They can now look on in quietness, and with complacency, while theologians charge each other with heresies. The change is so complete we are apt to forget that only three centuries ago it was dangerous to assert the motion of the Earth about the Sun; and that one of the greatest men of his age, John Calvin, the Protestant reformer, declared that we could not have antipodes, because they would fall off. A few generations of men come and go and all this is changed. This change has been firmly established by the discovery of the law which governs the motions of the heavenly bodies. The results of this discovery we see daily in the common calendars and almanacs, in the regulation of our clocks, and in the moving of railroad trains. These useful things come from the great annual ephemerides published by some of the principal governments. The oldest of these, and which is perhaps the most complete, is the *Connaisance des Temps*, published in Paris. This ephemeris was established in 1679 by Picard and through all the changes of the French government it has never failed to appear annually. It gives the position of the Moon for every hour of the year, the positions of the Sun and the planets for every day of the year, and the places of 318 of the principal fixed stars. Besides these matters are others deduced from the preceding, such as eclipses of the Sun and Moon, occultations of stars by the Moon, and the lunar distances for the use of navigators. The other national ephemerides are, in the order of their age, the *English Nautical Almanac*, the *Berliner Jahrbuch*, and the *American Ephemeris*. These works are generally published three or four years in advance, for the accommoda-

tion of navigators, and on the whole the accuracy of the predictions is remarkable. We may say that it requires an astronomer with good instruments in order to tell whether the predicted position of a planet or star is in error or not. This accuracy of prediction is the real test of a theory, The present method applied to the exact observations of modern times enables us to acquire in a few years a knowledge of the motions of the planets which the ancient astronomers obtained only by long and patient watching. A good way to see this is to examine our calendar. The year 1896 was a leap year, but the year 1900, four years after, will not be a leap year, since our calendar, which was designed to keep the church festivals at the proper time of the year, requires the omission of a day in 1900. In this way the Gregorian calendar produces an error of only one day in 3600 years, and the astronomers of the future will take care of that. But it is asserted that the ancient Chaldeans had devised a calendar which gives an error of a day in 10,000 years, or three times more accurate than our own. One would like to know how those old astronomers found so exactly the ratio between the length of a day and that of the tropical year. We can only guess. Historians tell us that the Chaldean records go back 4000 years before the Christian era, and recent investigations by some of the Jesuit Fathers nearly double this time. Perhaps therefore this long lapse of time eliminated the errors of the rude observations, and, by a purely empirical method, may have led to this very exact calendar. At the present time a few years of observation would fix this ratio with sufficient accuracy.

The change from empiricism to the scientific method was fairly begun two hundred years ago, or in 1687, when Newton published his "*Principia*." It is interesting to study this change, and to see how the new theories were criticised and opposed, and how they steadily gained ground, and at last were fully adopted. The changes of thought in many directions were very great. Great changes, however, do not come unprepared, and the words of Lagrange are true; that Newton was not only a great genius, but that he was a very fortunate man, or one of those men who appear at the right time. Copernicus had abolished the fixity of the Earth, Galileo had discovered the laws of motion, Kepler had worked out the laws of planetary motion, improvements had been made in the higher mathematics, and then came Newton, the right man at the right time. Of course it took many years for men to really see and comprehend the great law of nature which Newton had announced, and some time elapsed before it

was adopted. There were social and religious forces which opposed it. The theories of the schools had been formed under a very different system, and it was said that such a theory diminished respect for the Ruler of the Universe since it bound Him to act by a rigorous law. Hence arose a natural repugnance among many good people. When a great comet of threatening aspect appeared in the heavens, it had been the custom of the Church to command the comet to disappear. Newton showed that comets move around the Sun under the same law of attraction as the planets, and need cause no terror. But there was a special reason in England which delayed the recognition of Newton's discovery, outside a small number of learned men. This was the natural and good conservatism of the English people. They did not adopt our present calendar until a hundred and seventy years after it was established by Pope Gregory, and even then some of the country people refused to use it during their lives. De Morgan tells of a respectable old couple who always dressed and went to church on the wrong day of the week. Finding the church door closed the old gentleman would knock, wait awhile, then lift his hat and make a bow, and the good people walked home. The Gregorian calendar was devised to bring the church festivals at the proper seasons of the year, but for several centuries the church appears to have celebrated Christmas very well on the 15th day of December. It was the expanding trade of England, and the needs of her merchants that forced the adoption of the Gregorian calendar. Even in the great universities of England the discussion of Newton's law did not for a long time go much beyond mathematical puzzles and conundrums. Except Thomas Simpson, a self-taught weaver, there were few Englishmen during the first century after the publication of the *Principia* who did much to develop its doctrine. Newton himself withdrew from active scientific labors as he grew old and rich. In his old age he spent a good deal of time in examining theological questions, and it is supposed he became almost a Unitarian. He found certain passages in the New Testament which he declared were interpolations and spurious, and went so far as to write a letter on this subject to his friend John Locke. Then Newton became alarmed, and tried to suppress the letter, but it had been sent to the Continent, and parts of it were translated into French and printed. I think that Newton's statements have been adopted by modern scholars; but he was a cautious man, he did not wish to disturb his Trinitarian friends, and the English law prohibited Unitarians from holding office.

Biot, a French mathematician, has referred to this incident as evidence that Newton's mental powers had weakened, and Laplace has echoed the statement; but this is a mistaken notion, as is shown by the fact that Newton was still able to solve with ease the most difficult questions proposed by the Continental mathematicians. Newton was born a Puritan. He grew up in the times of the Commonwealth, and no doubt saw the Ironsides and the Major Generals. A few years ago Professor J. C. Adams brought to this country photographs of some of Newton's calculations, and of his college diary. He was a remarkably neat and accurate computer, and the diary shows him as a very conscientious young man. It was very natural, therefore, for him to resume in his old age and leisure the subjects which had occupied his youthful thought.

It was on the continent of Europe that the doctrines of Newton's great work were first fully adopted, and carried out with mathematical rigor. And curiously enough among the first to advocate the theory of Newton was Voltaire, who was no mathematician, but who may have been attracted by the simplicity of the theory, and who, perhaps, saw in it a weapon to be used against the church. At any rate Voltaire became an ardent advocate of the Newtonian theory, and together with Madam Châtelet, the respectable Emily, as he called her, he translated and published parts of the "*Principia*," and helped to bring it to the notice of men better fitted for such investigations. Among the first of these were Clairaut and D'Alembert. Clairaut applied the Newtonian theory to the motions of the Moon, and to the figure of the Earth. He died in 1765 at the early age of 52 years. D'Alembert was an "*enfan perdu*," picked up near the church of St. Jean Le Rond, and was adopted and brought up by the wife of a glazier. His unknown father furnished him an income of 1200 francs a year, and D'Alembert devoted himself to study in spite of the protests of his foster-mother. The good woman would expostulate with him and say, "Why do you want to be a philosopher, and what is a philosopher? He is a man who torments himself all his life in order that people may talk about him when he is dead." But D'Alembert went on with his studies and became the leading mathematical authority of France. He is better known generally as one of the encyclopedists, who are said to have done much to bring on the French Revolution. In astronomy he applied the Newtonian theory to the explanation of the precession and nutation of the equinoxes and his name is connected with a very general and useful method

for forming the equations of theoretical mechanics. Euler, born in Basel in 1707, was one of the most inventive and fertile mathematicians that ever lived. He is the founder of the theory of planetary perturbations. He worked in all branches of pure and applied mathematics, and did much to prepare the way for the two men who were to push the law of gravitation to its logical results.

In 1742 an edition of the *Principia* was published on the Continent. It was edited by two Jesuit Fathers and has copious notes explaining the difficult parts of the work. The editors were evidently very competent men. In their preface the Fathers make this curious statement: "Newton in this book assumes the hypothesis of the motion of the Earth; and the author's system could not be expounded except on the same hypothesis. Hence we have been obliged to assume a character other than our own; but we declare our obedience to the decree of the supreme pontiff against the motion of the Earth." It was not until 1818 that the pontifical curse was removed from the Copernican theory.

The French people have the power of producing clear and strong mathematical heads, and in Lagrange and Laplace this was well exemplified. Both were fortunate in living long and quiet lives in the midst of the turbulent times and wars of the Revolution. Lagrange perfected theoretical mechanics. In astronomy he showed how from the peculiar construction of our solar system we can determine the motions of the planets in a general manner. Perhaps no man ever lived who had greater analytical power, or a keener insight of the results of long and difficult transformations. Laplace devoted his life to the study of celestial mechanics. In his great work on this subject he undertook the solution of all the problems connected with the theory of the planets. Their motions are divided naturally into two parts. Some of the changes are periodical, and the planets return after a few years to their former positions. But others run through long periods of time, and these changes produce great alterations in the orbits. Such are the great variations in the excentricity of the Earth's orbit, and obliquity of the ecliptic, which are thought by some to have been the cause of the glacial epoch on the surface of the Earth. These changes are very important. They were carefully examined by Lagrange and Laplace, who proved, as they thought, that our solar system is stable; and that the great secular changes will come and go through very long intervals of time, amounting to tens and even

hundreds of thousands of years, but that the orbits will again come back to their former shapes and positions. Seventy years ago, when Laplace died in 1827, it was thought by many astronomers that nothing remained to be done in celestial mechanics but to correct the coefficients in the formulas of the Mecanique Celeste. But the passing years have changed all that, and parts of theory will have to be worked over anew. It is true that the great outlines of astronomy were marked out by Laplace, and his work is a monument of mathematical skill and vast labor. He has condensed into five moderate volumes the results of the life work of a remarkably able, ingenious, and industrious man. The Massachusetts sailor, who translated and explained this great work in four years, must have been a man of great intellectual power. Laplace has been well called the second Newton of theoretical astronomy. But while of similar mathematical genius he was in some respects a very different man. The son of a small farmer in Normandy, and born in 1749, Laplace grew up under the influence of the ideas and social forces which brought on the French Revolution. He has been charged with being a courtier, but in one thing he never changed, and this was his dislike, almost fierce, of the priests, to whom he generally referred as the men "in black coats." It was this feeling, apparently, which led him into a curious mistake. As it was customary to teach that the Moon was made to give us light at night, Laplace undertook to show how the arrangement of the Creator might be improved. He says: "If at the origin the Moon had been placed in opposition to the Sun, and at nearly four times its present distance, and the Earth and Moon had been started with parallel motions proportional to their distances from the Sun, the Moon would have always remained a full Moon, and thus would have replaced the light of the Sun." Unfortunately for Laplace the condition he has imagined is unstable, and at the slightest disturbance we should have lost our Moon. We are tempted to apply to Laplace one of his own mottoes: "*Opinionum commenta delet dies, naturae judicia confirmat.*"*

Time in fact which tests all things so severely, has shown that some of the results of theoretical astronomy are erroneous, and that others must be extended and completed. Thus the stability of our solar system was not proved, as was supposed, and although it would be wrong to call it unstable, yet the mathematical proofs given by Lagrange, Laplace and Poisson are not complete. Also the very important part of the changes of our

* Time destroys the fictions of opinion, and confirms the decisions of nature.

solar system which are called secular, because they run through long periods of time, need to be examined again. With our present formulas we can not go backward or forward from our epoch with certainty for more than a few centuries, and the improvement of these methods is an important and difficult question. The Swedish astronomer, Hugo Gyldén, who died a few months ago, was engaged on this problem.

But there is another source of difficulty in the planetary motions which the lapse of time is developing. While the Newtonian law of universal attraction represents the observations so well that it must be a real law of nature, yet there are indications of small forces which cause deviations from the principal force. Evidence of such a force is seen in the formation of the tails of comets when they approach the sun, since the particles appear to be thrown off by a repulsive force and we have here a new condition. There is also the question of a resisting medium in the planetary spaces. For many years it was thought that the existence of such a medium was shown by the motion of Encke's comet, but recent investigations have pretty much overthrown this idea, since the change in the orbit of the comet does not correspond to an acceleration of the motion, such as would result from a resisting medium. We are thrown back therefore on an unknown cause to account for these changes. The motion of our moon has been the subject of some of the most laborious researches ever undertaken in astronomy. The moon's motion is so rapid that any inaccuracy in its theory will soon appear. A good knowledge of this motion is closely connected with the art of Navigation, and the English government has expended large sums of money to perfect the lunar tables. But the last tables, computed by Hansen forty years ago, are now so much in error that it is necessary to correct them by an empirical method, since no defect has been found in theory. Delaunay devoted fifteen years of steady work to the motion of the moon, and produced the best theory we have, but the puzzling thing is that he agrees remarkably well with Hansen, who pursued a very different method and is certainly wrong. Here is another theoretical mystery. Another disturbance of this kind was found by Levrier forty years ago in the motion of the planet Mercury, and his result has been confirmed by the recent investigations of Professor Newcomb. The major axis of this planet is moving faster than it ought from the action of the known forces. In this case it is very certain that there is no defect in the theory, and we are obliged to search for a force that can produce this motion.

These are examples of what may happen in many cases, I think, when the Moon and the planets have been observed over long intervals of time. Should even very small forces act in our solar system so as to modify a very little the law of gravitation, the lapse of time, and the accurate observations of the present day, will bring to view the results of such actions. There will arise a condition in astronomy very different from that in which Laplace left it seventy years ago. But in any case the part of theoretical astronomy referring to the important secular changes in the orbits of the planets ought to be revised. Probably this will come with the improvement of mathematics, but it is not an easy task, since it requires a more general solution of the equations of motion.

Founded on the experimental laws of motion, and Newton's simple law of attraction, directly as the masses, and inversely as the squares of the distances, it needs only the creative Power to start the planets on their courses, and then theoretical astronomy becomes a great problem of mechanics. No other physical science has such a simple foundation, or has attained such accuracy of prediction.

1897, Mar. 2d.

THE STUDY OF THE VARIABLE STARS. IV.

PAUL S. YENDELL.

For Popular Astronomy.

2815 U Geminorum.

α	7^h	46^m	30^s	$\delta + 22°$	22′.7	(1855).
		49	10		15 .8	(1900).

About three and a half degrees southeast of κ Geminorum lies the most singular variable yet known to us.

It was discovered in 1855, by the English astronomer, Hind, and although it has been pretty continuously under observation since that time, we have as yet no certain knowledge of the law of its variation.

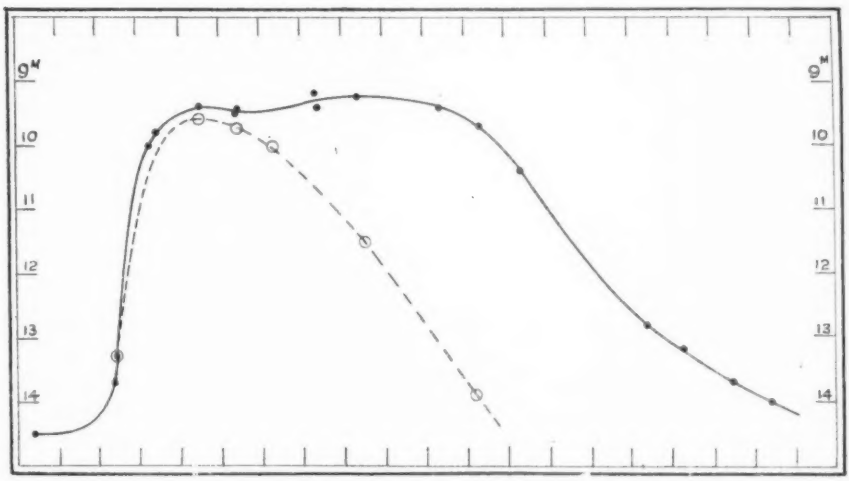
Its light-curve is peculiar, being entirely unlike that of any of the known periodic types of variable, but rather resembling, as has been remarked, a reversal of the Algol type of curve.

For fully three-fourths of its period it remains, with possible small fluctuations, at its normal faintness of $13^m.1$ (Schönfeld & Chandler). The rush up to maximum is the most rapid increase known to us, the greater part of the four magnitudes being gained within twenty-four hours. (See Mr. Sperra's observations in January P. A,, p. 390).

Its greatest light varies from $8^m.9$ to $9^m.7$, though most of the maxima seem to be passed at $9^m.1$ or $9^m.2$. It sometimes remains near the maximum for a week, the decrease being more or less rapid, sometimes as sudden, or nearly so, as the increase.

The light-curve—except the increase—is variable in its general character, but may be broadly divided into the "long" and the "short" types. The "long" type extends over a fortnight or three weeks; the "short" generally takes about ten days. For the examples of these two types of curve shown in Fig. 1, I am indebted to the kindness of the late Mr. George Knott, from whose observations, made in 1884 and 1885 the curves are drawn. The horizontal divisions represent single days.

FIGURE 1.

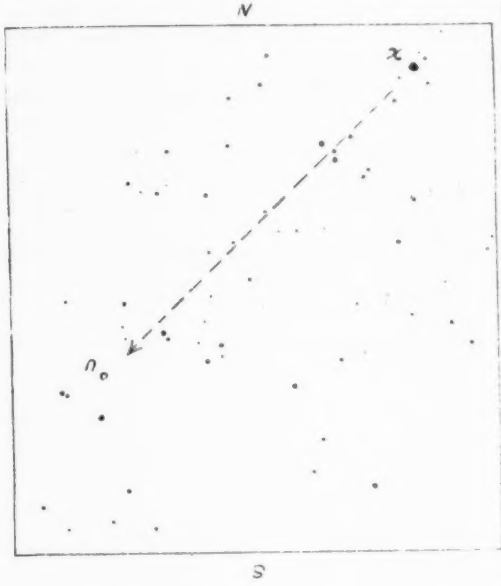


Mr. Knott (*Observatory*, Vol. V, p. 110) says that is of a bluish white color at the maximum, and is rather hazy, "almost suggesting the idea of a minute planetary nebula." It would seem from this that the spectrum of the star would show bright lines, or at any rate some distinguishing peculiarity: but Dr. Copeland and Professor Pickering have both examined it, and both report an entirely normal spectrum, with nothing peculiar about it. I have sometimes thought it a little difficult to focus at maximum, but never to the extent noted by Mr. Knott, who, however, was a careful observer, and paid much attention to this particular star.

Chandler gives as elements in his Third Catalogue, the date of the last well-determined maximum and the probable mean period, with the remark "large irregularities."

The elements are Max. 1895 Oct. 23 + 86*d*.3 E.

FIGURE 2.



There is scarcely a doubt that the great irregularities of this star are of a periodic character; the intervals between the maxima, according to Knott, vary from 71 to 126 days, but the mean period seems to be as above: this is not very certain, however, for large gaps of five or more periods occur in the series of observed dates, and the true number of periods elapsed since its discovery is not certainly known, as it is impossible to be sure, within one, of the number contained in a gap of three or more periods.

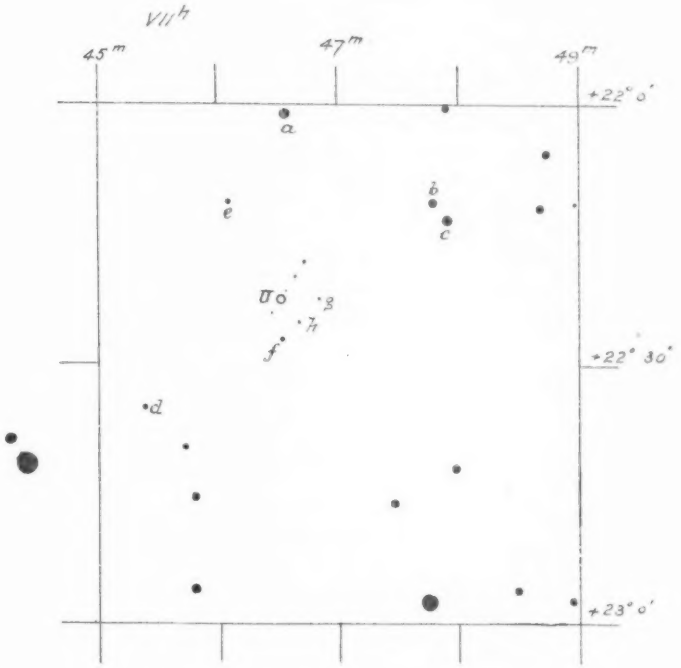
The comparison-stars, with their positions for 1855, and their magnitudes, are as follows:

	α			δ		Mag.
	h	m	s	°	′	
a	7	46	34	+ 22	1.2	8.6
b		47	48		11.2	9.3
c		47	56		13.2	9.2
d		45	23		35.2	10.3
e		46	1		11.2	10.6
f		46	30		32.8	11.2
g		46	46		38.8	12.3
h		46	34		25.2	12.4

The star is easy to find; its position for 1900 is given at the head of this paper. Those whose telescopes are not equipped with circles, can easily sweep it up, about 3½°, almost exactly south following $\varkappa$ (Kappa) Geminorum (which is 3° south from Pollux), as shown in the subjoined map (Fig. 2).

It forms an equilateral triangle with *a* and *c*, as will be seen from the above map and Fig. 3, which shows the principal stars of the region, on a larger scale.

FIGURE 3.



If as close a watch as possible were kept on this star, it would seldom or never happen that an interval of more than two periods would slip by without an observed maximum. For this reason, it is very desirable that every one who is observing with as much as two inches of aperture should give at least one look for U Geminorum on each evening or morning when he is working.

Within the last year a variable has been announced (SS Cygni) which seems almost certain to prove a second example of this type. My observations and those of Mr. Parkhurst in December and January last, point strongly to this conclusion. In POPULAR ASTRONOMY for February, 1897, p. 446, Mr. Parkhurst gives sufficient particulars to guide any one wishing to observe the star.

AN ATLAS OF VARIABLE STARS IN PREPARATION.

REV. J. C. HAGEN.

(Abridged for POPULAR ASTRONOMY from a paper in the *Vierteljahrsschrift*, Vol. 31, part 4, by Rev. J. C. Hagen, Director of the Georgetown College Observatory, Washington, D. C.)

The need of an atlas of variable stars arises from the fact that the faint minima are seldom observed, and that no great telescope is devoted to this branch of astronomy. The labor of identifying faint variables is equally great and only the slightest aid is afforded by the occasional publication of data for the neighboring faint stars, such as have been given by Schönfeld and Chandler. The identification of the brighter variables is not entirely without difficulty, especially for beginners, aside from the fact that the Bonn charts can no longer be bought. Even for the brightest variables it would be a saving of labor if lists of suitable comparison stars, with their magnitudes determined, were at hand.

I have wished to prepare such an atlas for thirteen years. The means for this work was first offered me when I undertook the arrangement and direction of the Observatory of Georgetown College, eight years ago. The work on the charts is already begun, and completed for the first series, including about fifty charts. It seems, therefore, to be time to make a preliminary report on the plan of the work, the method of observation, and the arrangement of the charts.

The plan of the atlas is determined by the considerations that it shall contain only the stars needed for the certain identification of the variable, but that the data for magnitude shall be as accurate as possible. The requirements are the reverse of those for the ecliptic charts, of which we possess several incomplete series, and whose object is to facilitate the discovery of new asteroids.

The atlas is to contain all the variables of 25° south declination, numbering about 250. The stars are divided into three classes, according to the instruments and charts needed to observe them:

The completion of this important project will mark an epoch in the history of variable star work. The charts will bear the same relation to variable stars that the Durchmusterung charts bore to the astronomy of a generation ago. There are many who would be glad to take part in this interesting work if only they were provided with means for conveniently identifying the variables, and they will rejoice that soon these means are to be provided. The name of the distinguished astronomer having the work in charge is a guarantee that it will be well and thoroughly done. The appearance of these charts will be awaited with great interest. J. A. PARKHURST.

The first class contains those variable stars, for the observation of whose minima a three inch comet-seeker, and therefore also the Bonn charts, are not sufficient. There are, in round numbers 150 variables in this class.

The second class contains those for which a three-inch is necessary and sufficient. For this class the Bonn charts will also answer. There are 50 or 60 of these variables.

The third class contains those variables which can be completely observed with the naked eye or an opera glass, and for which Heis' or Klein's atlas will answer. There are about 50 or 60 of these stars.

From this division there follows immediately the limits of magnitude for the last two classes. From the first class the limit was given by the instrument of the Georgetown Observatory. This is a 12-inch refractor, whose lowest power eyepiece has a 4-inch lens and magnifies about 45 times (in diameter) with a field of three-fourths of a degree. All the stars visible in this eyepiece are given, and the limit of visibility is assumed to be the 13.5 magnitude.

II. The observations. The arrangement of the charts is, of course, different for each of the three classes.

1. For the first class a field 1° square is taken, with the variable in the center. All the Durchmusterung are then entered in this field. The fainter stars cover only one quarter of the field, that is a square one half degree on each side. This small field gives comparison stars in great numbers. The places and magnitudes of these stars are then determined anew by the method used by the Durchmusterung observers. The micrometer consists of a semi-circular glass scale whose divisions, just 3′ of arc apart, are visible without field illumination.

Declination, right ascension and magnitude are determined separately, so that no assistant is needed. For the measures of declination the telescope follows the stars, which allows plenty of time, so that the estimates are made only once. They are entered in pencil on the charts

The right ascensions are determined by the chronograph, three successive measures being made. In this way the north and south halves of the field are treated separately. These position measures are relative, being referred to the variable as a zero point, and are so entered in the catalogue.

The magnitudes are also relative, being determined by the method of sequences, on a scale joining as closely as possible to that of the Durchmusterung. (Here are omitted some considera-

tions in regard to the magnitudes of the faintest stars given on the charts).

2. In the second class of charts, for use with a 3-inch glass, a field is chosen twice as large in each co-ordinate, therefore 2° square, with the variable in the center. One quarter of this field, that is 1° square, is more thickly set with small stars than the rest of the chart. This small field contains all the Durchmusterung stars, while the outer part has only those brighter stars needed for identification of the variable, or as comparison stars.

The magnitudes of all these stars are determined anew, but not the positions, except in cases where the Durchmusterung is lacking or erroneous.

3. The third class, which are observed with the naked eye, differs from the first and second in that not all the stars down to a certain magnitude are included, but only those which are useful or necessary for identification or as comparison stars. Neither the positions or magnitudes of these stars are determined anew, but the peculiarity of this class consists in the fact that the endeavor is made to include only the historical comparison stars, that is, those which have been actually used by a number of observers. All these charts are, however, compared with the heavens, and where it is evident that more stars are needed, they are chosen by comparison with the variable, and included.

The accompanying catalogue of this class gives the name of the observer by whom the comparison star has been used, the position of the star, and finally several series of magnitude determinations from the principal sources.

III. The charts for all three classes have the same size and shape, 157mm square. The appearance of the first and second is the same, though the linear scales are in the ratio of 1 to 2. The smaller, more thickly set square is separated from the rest of the chart by red lines. The variable is in the center and is represented in the usual way by a point within a circle. The size of the circle shows the maximum, that of the point the minimum magnitude.

In the third class it was not considered necessary that each chart should contain only one variable, but the 50 or 60 variables are collected on about 20 charts. The scales are therefore very different, according to the number and extent of the included constellations.

The coördinate lines are printed in red, so that the charts when viewed by red light (which is the best for the eye) shall have the appearance of the heavens.

In the third class the projection is conic; in the first two, one

similar to that of Mercator, in that the parallels are rectilinear and drawn at equal distances apart. The distortion is unnoticeable, on account of the smallness of the field.

The title of the charts contains all that is needed at night at the telescope, that is, name, position for 1900 with precession, color and spectrum of the variable and amplitude of the light change. The accompanying catalogue gives all that is needed in the reductions, as nomenclature and magnitude of the comparison stars, epoch and period of the variable.

. . . . Class 1 is divided into three zones or series, the first containing the variables south of the equator, the second, those from the equator to 25° north declination, the third the remaining variables to the pole. Each of these series has in round numbers 50 charts. Each of the other classes constitutes a series, so that the whole atlas contains five series of about 50 variables each. These series will be published separately, so that every observer can obtain those which are suited to his geographical position and instrumental equipment. He will find therein the whole program of work and all needed data ready to hand; and, what is the main object, will be able to identify the variables with certainty. No chart will be printed till the variable is shown to be such by observation. . . . .

MIRAGE.

C. M. CHARROPPIN, S. J.

FOR POPULAR ASTRONOMY.

Punta Gorda and its surroundings present to all lovers of nature one of the most picturesque landscapes of British Honduras. The many verdant islands profusely scattered by Dame Nature along the northeastern coast—the giant mountains of Guatemala rearing aloft their craggy crests even unto the clouds, the long mist-gathering range across the bay, disappearing softly into a distant perspective, the broken and scattered hills of Toledo, shaping themselves into an artistic background to our coy little hamlet, resting modestly in the tropical shade of its thousand cocoa-nut trees are sceneries worthy of the painter's brush as well as the poet's pen.—But since I am neither an artist nor a poet, at the very outset, I must check my rambling pen, for fear that some martial reader may hurl at my head this Spartan dart, "Sutor ne crepitat." Science is my business, and this tiny sketch is supposed to be a scientific article.

It was the 5th of February, 1897. Our dazzling orb following its path along the ecliptic was about to sink into the western horizon. A gorgeous sunset caused every cloudlet to glow with golden and purple tints which defy the artist's brush at reproduction.

Who is he that has visited Punta Gorda and has not heard of Mohaw Caye? A beautiful little island shaped like a basket of mossy green resting on the bosom of the deep. Two tall cocoanut trees, at each extremity of the island, give the appearance of the two handles of a basket. Mohaw island is about seven miles from Punta Gorda, in a north-easterly direction. It is a beacon to mariners, a Mecca to fishermen and a lovely and familiar sight to the villagers of Punta Gorda.

On the memorable 5th of February, Mohaw island had begotten an offspring. It had reproduced itself and the two islands stood apparently side by side, floating as it were upon the unruffled surface of a calm sea, an object of wonder and admiration to the bewildered inhabitants of our thriving town. Some of our citizens, especially those grave seers, who had acquired the wisdom of old age and the experience of untold adventures, but whose eyesight meanwhile had become dim, thought that the idea of a new island springing up as it were by the wand of magic, was a theory altogether unadmisible. They were therefore non-commital: but their unbroken silence was compromising their reputation for occult knowledge. Had they not before interpreted correctly the mysterious signs of the zodiac? Had they not successfully predicted rain, during the rainy season, at all the changes of the Moon? Were they not able to expound to the great satisfaction of their audience all the intricate mysteries of the almanac? And now was this simple phenomenon to baffle their foresight and cast into oblivion the victories won on many a well fought field? Therefore a verdict was to be rendered and it was declared deliberately, soberly and without the shadow of a doubt. The vision was no new island; but it was a man-of-war of gigantic proportion entering the harbor of Punta Gorda. The news spread like wild fire among our villagers that Punta Gorda was being honored by the visit of a man-of-war in her Majesty's service. The faithful constable at his post, at once rushed to the magistrate of the town, to announce the glad tidings of a man-of-war entering the harbor, and to enquire of his superior, what preparations should be made for the worthy reception of so honored a guest. Our good doctor smiled as he recognized at once the phenomenon. He told his subordinate

that it was nothing else but a mirage; adding with a squint of the eye that there was no preparation needed. The news, however, spread all through the hamlet that the seers were once more correct. The keen-sighted magistrate had confirmed their wise decision. It was really "The Mirage" in her majesty's service entering the harbor.

Meanwhile the Punta Gorda telescope with a terrestial eyepiece was taking the angle of parallax between the real and the fictitious Mohaw island. That angle was found to be 7 degrees and 15 minutes from center to center. The two islands were very distinct in the telescope, only the refracted image was inverted and its apex possibly 4 degrees above the sea level. Besides the telescope showed plainly what the naked eye could not discern, a second image no longer inverted, but upright in position and situated north-west of the island. The second refraction was somewhat fainter, but higher in altitude. The three islands formed an obtuse angled triangle; the obtuse angle being at the real island and not greater than 100 degrees.

We had then a real mirage, not in her majesty's service, but according to the optical laws which the King of Kings has impinged upon nature. On the 5th of February the atmospheric conditions were favorable for a mirage. The two preceding days were unusually cool. They were followed by a warm day. This sudden change of temperature must have caused different strata, or currents of cold and warm air—conditions necessary for a mirage. Again the atmosphere was saturated with moisture from previous rain. The mirage was so low in altitude as to be mistaken for a man-of-war ploughing the deep. The altitude of a mirage depends greatly on the altitude of the Sun, but most of all on the condition of the atmospheric strata. When the Sun culminates in tropical climes a mirage becomes impossible.

What is then a mirage? It is nothing else but an optical illusion. A mirage is the appearance of some object projected generally against the sky, but sometimes against sea or land, caused by an unequal refraction of the solar rays in the lower strata of our atmosphere. We are living at the bottom of an ocean of air, which diminishes in density as it becomes remote from our planet. As we ascend the air becomes more rarified until finally it mingles with the ether in space. The ether of space, however, permeates the atmosphere and penetrates even to the center of the Earth. Generally speaking the more rarified the air is the cooler it becomes. But it happens sometimes that the lower strata of air are cooler than the upper strata, a pencil of light

under such condition instead of ascending obliquely by reflection, may travel a short distance horizontally and by refraction be bent towards the Earth, reaching it at a distant point. An observer at that point may perceive distant objects elevated in the sky and inverted. Such a sight is called a mirage.

But the mirage of Mohaw island as seen in Punta Gorda was very near the generating object, of a low altitude and double in appearance, one image being inverted and the other erect. The double refraction is generally caused by an intermediate stratum between the cold and warm currents of air. Generally speaking, a double refraction only takes place when the object is below the horizon from the point of view. The nearness of the mirage from its primary object and its low altitude may have originated from two causes. 1st, the low altitude of the Sun and 2d, a rapid diminution of the density of the air having strata of different temperature. I may add a 3d reason, viz.: that the lowest stratum of air instead of being cooler, as is the case with most mirage, especially of those seen in the Arctic seas, was warmer as is the case with the mirage of the Sahara.

PUNTA GORDA, British Honduras,
March 12th, 1897.

THE STORY OF A SPECULUM.

ALDEN W. QUIMBY.

FOR POPULAR ASTRONOMY.

A score of miles west of Broad Street station, Philadelphia, the famous "Chicago Limited" thunders past Malvern, a growing borough perched on the southern enclosing ridge of the beautiful Chester Valley. It is classic ground, for only a half mile to the southward a pair of monuments, and two cannon of antique pattern, designate the arena of the "Paoli Massacre;" while at the same distance to the north there still stands a portion of the old "Warren Tavern," near which were drawn up in battle array the contending armies of Washington and Howe, prevented only from a most sanguinary engagement by a violent rain storm, which ruined their ammunition. And a few miles to the northeast, the historic hills of Valley Forge loom up to the view of the delighted tourist.

Four miles north of Malvern, at the foot of the North Valley Hill, and commanding a fine sweep of the charming valley, is the

spacious farm house of the late Esquire McCurdy, which still contains an excellent library of literary and scientific works current a quarter of a century ago. Their owner, who was also a surveyor, would have been proud indeed, could he have foreseen the achievement of his son and successor in the peaceful pursuits of agriculture, Mr. C. Wesley McCurdy, in the creation of the speculum of a reflecting telescope.

The latter gentleman, in whom the mechanical instinct is strong, happened to purchase a fine eight and one half inch Calver mirror, which he mounted most elaborately. After a brief honeymoon with rare celestial objects, he conceived the project of grinding a mirror of much greater dimensions. Prodigious task! If there be a school for patience entitled to extraordinary rank for the Spartan severity of its curriculum, surely it is this. With what avidity would we peruse the diaries of its graduates, recording the myriad incidents of their unremitting toil in fields of scientific research. But, alas, inexorable time neither permits the reading nor the writing. Herschel, spoon-fed by his sister, in the critical moments of the completion of one of his highly important tasks, is the illustrious representative of a class of consecrated students of nature, whose arduous labors and intense devotion can never receive their fullest meed of praise from an uncomprehending public.

How dear to the worker are the very tools he employs, and the innumerable odds and ends he accumulates in the construction of his prize. The little basket of tubes and diaphragms, lenses and prisms, springs and screws, wires and strings, becomes "a thing of beauty and a joy forever." The mistress of the household recognizes the weakness of the tyro, and with malicious playfulness advises him to add to his store some insignificant scraps to which she directs his attention.

Mr. McCurdy procured from the Smithsonian Institution a copy of Draper's pamphlet, describing his method of grinding a speculum. Then, having purchased two glass disks, fourteen and a half inches in diameter, he proceeded to convert one into a concave mirror by grinding the other upon it, after the Draperian formula. His workshop was the loft of one of the outbuildings of the farm, and a barrel served as a convenient work-bench, because it was necessary to constantly move about it. It was practically an illustration of "perpetual motion;" and the whole process was a literal proof of the truth of the maxim "*Per aspera ad astra*."

By the use of emery of various degrees of elutriation, the hard

crystal surface was gradually reduced to a becoming concavity; but weeks and months elapsed before the fruits of this severe toil became apparent. The duties of the farm were exacting, and only the early morning and late evening hours, with here and there a rainy day, could be devoted to such blissful employ. Testing the glass at night upon an artificial star—a delicate aperture in a metallic shield surrounding a kerosene lamp—added weirdness to the engrossing study; and, doubtless, those persons who imagined Nasmyth, flitting about in the dead of night in the summer season, clad only in his night-dress, and carrying his telescope, to be "a ghost with a coffin under his arm," would have peered at the spectral scene with no little fluttering of heart.

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SOLAR ECLIPSES. (*Continued*).

J. MORRISON, M. A., M. D., PH. D.

FOR POPULAR ASTRONOMY.

TO ESTABLISH CRITERIA FOR DETERMINING WHETHER THE ECLIPSE IS BEGINNING OR ENDING AT ANY PLACE PREVIOUSLY FOUND.

When a place is on the surface of the cone of the shadow the eclipse is either beginning or ending there. If T denote the time

It was the 5th of February, 1897. Our dazzling orb following its path along the ecliptic was about to sink into the western horizon. A gorgeous sunset caused every cloudlet to glow with golden and purple tints which defy the artist's brush at reproduction.

Who is he that has visited Punta Gorda and has not heard of Mohaw Caye? A beautiful little island shaped like a basket of mossy green resting on the bosom of the deep. Two tall cocoanut trees, at each extremity of the island, give the appearance of the two handles of a basket. Mohaw island is about seven miles from Punta Gorda, in a north-easterly direction. It is a beacon to mariners, a Mecca to fishermen and a lovely and familiar sight to the villagers of Punta Gorda.

On the memorable 5th of February, Mohaw island had begotten an offspring. It had reproduced itself and the two islands stood apparently side by side, floating as it were upon the unruffled surface of a calm sea, an object of wonder and admiration to the bewildered inhabitants of our thriving town. Some of our citizens, especially those grave seers, who had acquired the wisdom of old age and the experience of untold adventures, but whose eyesight meanwhile had become dim, thought that the idea of a new island springing up as it were by the wand of magic, was a theory altogether unadmisible. They were therefore non-commital: but their unbroken silence was compromising their reputation for occult knowledge. Had they not before interpreted correctly the mysterious signs of the zodiac? Had they not successfully predicted rain, during the rainy season, at all the changes of the Moon? Were they not able to expound to the great satisfaction of their audience all the intricate mysteries of the almanac? And now was this simple phenomenon to baffle their foresight and cast into oblivion the victories won on many a well fought field? Therefore a verdict was to be rendered and it was declared deliberately, soberly and without the shadow of a doubt. The vision was no new island; but it was a man-of-war of gigantic proportion entering the harbor of Punta Gorda. The news spread like wild fire among our villagers that Punta Gorda was being honored by the visit of a man-of-war in her Majesty's service. The faithful constable at his post, at once rushed to the magistrate of the town, to announce the glad tidings of a man-of-war entering the harbor, and to enquire of his superior, what preparations should be made for the worthy reception of so honored a guest. Our good doctor smiled as he recognized at once the phenomenon. He told his subordinate

that it was nothing else but a mirage; adding with a squint of the eye that there was no preparation needed. The news, however, spread all through the hamlet that the seers were once more correct. The keen-sighted magistrate had confirmed their wise decision. It was really "The Mirage" in her majesty's service entering the harbor.

Meanwhile the Punta Gorda telescope with a terrestial eyepiece was taking the angle of parallax between the real and the fictitious Mohaw island. That angle was found to be 7 degrees and 15 minutes from center to center. The two islands were very distinct in the telescope, only the refracted image was inverted and its apex possibly 4 degrees above the sea level. Besides the telescope showed plainly what the naked eye could not discern, a second image no longer inverted, but upright in position and situated north-west of the island. The second refraction was somewhat fainter, but higher in altitude. The three islands formed an obtuse angled triangle; the obtuse angle being at the real island and not greater than 100 degrees.

We had then a real mirage, not in her majesty's service, but according to the optical laws which the King of Kings has impinged upon nature. On the 5th of February the atmospheric conditions were favorable for a mirage. The two preceding days were unusually cool. They were followed by a warm day. This sudden change of temperature must have caused different strata, or currents of cold and warm air—conditions necessary for a mirage. Again the atmosphere was saturated with moisture from previous rain. The mirage was so low in altitude as to be mistaken for a man-of-war ploughing the deep. The altitude of a mirage depends greatly on the altitude of the Sun, but most of all on the condition of the atmospheric strata. When the Sun culminates in tropical climes a mirage becomes impossible.

What is then a mirage? It is nothing else but an optical illusion. A mirage is the appearance of some object projected generally against the sky, but sometimes against sea or land, caused by an unequal refraction of the solar rays in the lower strata of our atmosphere. We are living at the bottom of an ocean of air, which diminishes in density as it becomes remote from our planet. As we ascend the air becomes more rarified until finally it mingles with the ether in space. The ether of space, however, permeates the atmosphere and penetrates even to the center of the Earth. Generally speaking the more rarified the air is the cooler it becomes. But it happens sometimes that the lower strata of air are cooler than the upper strata, a pencil of light

under such condition instead of ascending obliquely by reflection, may travel a short distance horizontally and by refraction be bent towards the Earth, reaching it at a distant point. An observer at that point may perceive distant objects elevated in the sky and inverted. Such a sight is called a mirage.

But the mirage of Mohaw island as seen in Punta Gorda was very near the generating object, of a low altitude and double in appearance, one image being inverted and the other erect. The double refraction is generally caused by an intermediate stratum between the cold and warm currents of air. Generally speaking, a double refraction only takes place when the object is below the horizon from the point of view. The nearness of the mirage from its primary object and its low altitude may have originated from two causes. 1st, the low altitude of the Sun and 2d, a rapid diminution of the density of the air having strata of different temperature. I may add a 3d reason, viz.: that the lowest stratum of air instead of being cooler, as is the case with most mirage, especially of those seen in the Arctic seas, was warmer as is the case with the mirage of the Sahara.

PUNTA GORDA, British Honduras,
March 12th, 1897.

THE STORY OF A SPECULUM.

ALDEN W. QUIMBY.

FOR POPULAR ASTRONOMY.

A score of miles west of Broad Street station, Philadelphia, the famous "Chicago Limited" thunders past Malvern, a growing borough perched on the southern enclosing ridge of the beautiful Chester Valley. It is classic ground, for only a half mile to the southward a pair of monuments, and two cannon of antique pattern, designate the arena of the "Paoli Massacre;" while at the same distance to the north there still stands a portion of the old "Warren Tavern," near which were drawn up in battle array the contending armies of Washington and Howe, prevented only from a most sanguinary engagement by a violent rain storm, which ruined their ammunition. And a few miles to the northeast, the historic hills of Valley Forge loom up to the view of the delighted tourist.

Four miles north of Malvern, at the foot of the North Valley Hill, and commanding a fine sweep of the charming valley, is the

spacious farm house of the late Esquire McCurdy, which still contains an excellent library of literary and scientific works current a quarter of a century ago. Their owner, who was also a surveyor, would have been proud indeed, could he have foreseen the achievement of his son and successor in the peaceful pursuits of agriculture, Mr. C. Wesley McCurdy, in the creation of the speculum of a reflecting telescope.

The latter gentleman, in whom the mechanical instinct is strong, happened to purchase a fine eight and one half inch Calver mirror, which he mounted most elaborately. After a brief honeymoon with rare celestial objects, he conceived the project of grinding a mirror of much greater dimensions. Prodigious task! If there be a school for patience entitled to extraordinary rank for the Spartan severity of its curriculum, surely it is this. With what avidity would we peruse the diaries of its graduates, recording the myriad incidents of their unremitting toil in fields of scientific research. But, alas, inexorable time neither permits the reading nor the writing. Herschel, spoon-fed by his sister, in the critical moments of the completion of one of his highly important tasks, is the illustrious representative of a class of consecrated students of nature, whose arduous labors and intense devotion can never receive their fullest meed of praise from an uncomprehending public.

How dear to the worker are the very tools he employs, and the innumerable odds and ends he accumulates in the construction of his prize. The little basket of tubes and diaphragms, lenses and prisms, springs and screws, wires and strings, becomes "a thing of beauty and a joy forever." The mistress of the household recognizes the weakness of the tyro, and with malicious playfulness advises him to add to his store some insignificant scraps to which she directs his attention.

Mr. McCurdy procured from the Smithsonian Institution a copy of Draper's pamphlet, describing his method of grinding a speculum. Then, having purchased two glass disks, fourteen and a half inches in diameter, he proceeded to convert one into a concave mirror by grinding the other upon it, after the Draperian formula. His workshop was the loft of one of the outbuildings of the farm, and a barrel served as a convenient work-bench, because it was necessary to constantly move about it. It was practically an illustration of "perpetual motion;" and the whole process was a literal proof of the truth of the maxim "*Per aspera ad astra*."

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crystal surface was gradually reduced to a becoming concavity; but weeks and months elapsed before the fruits of this severe toil became apparent. The duties of the farm were exacting, and only the early morning and late evening hours, with here and there a rainy day, could be devoted to such blissful employ. Testing the glass at night upon an artificial star—a delicate aperture in a metallic shield surrounding a kerosene lamp—added weirdness to the engrossing study; and, doubtless, those persons who imagined Nasmyth, flitting about in the dead of night in the summer season, clad only in his night-dress, and carrying his telescope, to be "a ghost with a coffin under his arm," would have peered at the spectral scene with no little fluttering of heart.

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When a place is on the surface of the cone of the shadow the eclipse is either beginning or ending there. If T denote the time

of such an occurrence then at the next instant $T + dT$, the place will be either *within* or *without* the shadow according as the eclipse is beginning or ending at the time T, that is to say, the eclipse is beginning or ending according as the distance of the place from the axis of the shadow is, at the time $T + dT$, less or greater than the radius of the shadow at that place, therefore if

$\triangle < l - i\zeta$, the eclipse is beginning.
$\triangle > l - i\zeta$, the eclipse is ending.

In total eclipses $l - i\zeta$ is negative, but by comparing $\triangle^2$ with $(l - i\zeta)^2$ the criterion will still hold.

Since $(l - i\zeta)^2 = (x - \xi)^2 + (y - \eta)^2$, the criterion of beginning or ending for both partial or total eclipses will be the negative or positive value of the differential coefficient of the quantity $(x - \xi)^2 + (y - \eta)^2 - (l - i\zeta)^2$ taken with regard to the time.

Differentiating this expression, T being the independent variable we have

$$(x - \xi)\left(\frac{dx}{dT} - \frac{d\xi}{dT}\right) + (y - \eta)\left(\frac{dy}{dT} - \frac{d\eta}{dT}\right) - (l - i\zeta)\left(\frac{dl}{dT} - i\frac{d\zeta}{dT}\right)$$

in which we regard i as constant, its variation during an eclipse being practically insensible. For the sake of brevity, it is expedient to write, x', y', ξ', etc., for

$$\frac{dx}{dT}, \frac{dy}{dT}, \frac{d\xi}{dT} \text{ etc.}$$

and to represent the quantity by P, after first substituting the values of $x - \xi = (l - i\zeta) \sin Q$, $y - \eta = (l - i\zeta) \cos Q$ and $l - i\zeta = L$, we get

$$P = L\,[(x' - \xi') \sin Q + (y' - \eta') \cos Q - (l' - i\zeta')] \quad (96)$$

and if we represent by P' the quantity within the brackets we shall have

$$P = P'L \quad (97)$$

from which we see that P will be positive or negative according as P' and L have like or unlike signs.

Now in total eclipses L is negative, therefore from the preceding we shall have when

P' is *positive*, eclipse *beginning*.
P' is negative, eclipse ending.

But in external contacts and internal contacts in the case of annular eclipses L is positive, therefore we have when

P' is negative, eclipse beginning.
P' is positive, eclipse ending.

We must now put the expression for P', viz:

$$P' = (x' - \xi') \sin Q + (y' - \eta') \cos Q - (l' - i\zeta') \quad (98)$$

in a convenient form for computation. The quantities x', y', l', ξ' η' and ζ' may be taken for the hourly variations of x, y, l, ξ, η and ζ respectively, but greater accuracy will be secured by taking for them the variations in 10 minutes. The first three can be easily deduced from the eclipse tables or Besselian Elements for the given date, but the last three can only be obtained by differentiating (60), the latitude and longitude of the place being regarded constant, and since

$$\theta = \mu - a = \mu_1 - \lambda, \quad \frac{d\theta}{dT} = \frac{d\mu_1}{dT},$$

but θ is expressed in angular measure and in order that all the quantities may be homogeneous, we must express $\frac{d\mu_1}{dT}$ in circular measure by multiplying it by sin 1″, therefore we have $\mu' = \frac{d\mu_1}{dT} \sin 1''$ and for a similar reason we have $d' = \frac{dd}{dT} \sin 1''$ where μ' and d' are the hourly variations or variations for 10 minutes of μ or θ and d respectively.

Differentiating (60) we have

$$\begin{aligned}
\xi' &= \mu' \rho \cos \varphi' \cos \theta \\
&= \mu' (-\eta \sin d + \zeta \cos d) && \text{by the aid of (60)} \\
&= \mu' (-y \sin d + \zeta \cos d + l - i\zeta) \sin d \cos Q) && \text{by (68)} \\
\eta' &= -\rho d' \sin \varphi' \sin d - \rho d' \cos \varphi' \cos d \cos \theta + \rho \mu' \cos \varphi' \sin d \sin \theta \\
&= \mu' \xi \sin d - d' \zeta \\
&= \mu' [x \sin d - (l - i\zeta) \sin d \sin Q] - d' \zeta && \text{by (78)} \\
\zeta' &= \rho d' \sin \varphi' \cos d - \rho d' \cos \varphi' \cos \theta \sin d - \rho \mu' \cos \varphi' \cos d \sin \theta \\
&= -\mu' \xi \cos d + d' \eta \\
&= \mu' [-x \cos d + (l - i\zeta) \cos d \sin Q] + d' [y - (l - i\zeta) \cos Q]
\end{aligned}$$

Substituting these in (98) reducing and omitting terms involving i^2 and id' as practically inappreciable we have

$$\begin{aligned}
P' = &(-l' - i\mu' x \cos d) - (-y + \mu' x \sin d) \cos Q \\
&+ (x + \mu' y \sin d + i\mu' l \cos d) \sin Q \\
&- \zeta (\mu' \cos d \sin Q - d' \cos Q)
\end{aligned}$$

For brevity put

$$\begin{aligned}
a' &= -l' - i\mu' x \cos d \\
b' &= -y + \mu' x \sin d \\
c' &= +x + \mu' y \sin d + i\mu' l \cos d
\end{aligned} \quad (99)$$

then the above becomes

$$P' = a' - b' \cos Q + c' \sin Q - \zeta (\mu' \cos d \sin Q - d' \cos Q) \quad (100)$$

The quantities a', b', c' can be computed for the same dates as the other quantities in the eclipse tables and interpolated for intermediate dates. They must also be computed for both penumbral and umbral contacts; the values of b' will be the same for both but those of a' and c' will differ by reason of the different values of l' and l.

For convenience of logarithmic computation we put

$$\begin{aligned} e \sin E &= b' & f \sin F &= d' \\ e \cos E &= c' & f \cos F &= \mu' \cos d \end{aligned} \quad (101)$$

then we get

$$P' = a' + e \sin (Q - E) - \zeta f \sin (Q - F) \quad (102)$$

The quantities a' and F are always very small and may generally be neglected when the sign of P' is alone required, we may also use ζ_1 for ζ the former being derived from

$$\zeta_1 = \cos \beta - i \sin \beta \cos (Q - \gamma)$$

(81 *et seq*) and the latter from (83). Therefore we have with all the accuracy necessary in such cases, the following simple criteria for partial or annular eclipses, viz:

$$\begin{aligned} e \sin (Q - E) &< \zeta f \sin Q, \text{ eclipse beginning} \\ e \sin (Q - E) &> \zeta l \sin Q, \text{ eclipse ending} \end{aligned} \quad (103)$$

and for total eclipses

$$\begin{aligned} e \sin (Q - E) &> \zeta f \sin Q, \text{ eclipse beginning} \\ e \sin (Q - E) &< \zeta l \sin Q, \text{ eclipse ending} \end{aligned} \quad (104)$$

Before we can use these criteria we first determine the latitude and longitude of the place by (86) for any assumed time between the beginning and ending of the eclipse on the Earth generally and also for such an assumed value of Q as will not give an impossible result. When the penumbra falls completely within the Earth's disk Q can of course have any value from 0° to 360° as in the outline *bt* Fig. 1.

We then compute the values of e, f and E from (101), b' and c' being interpolated for the given date from the tables of values previously computed from (99).

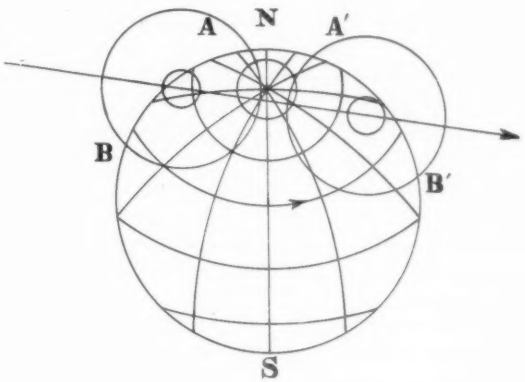
Rising and Setting Limits.

These limits are the curves passing through all the points on the Earth's surface where the eclipse begins or ends at sunrise or

sunset. In this case we have the point Z in the horizon and $\zeta_1 = 0$ as the conditions which must be satisfied.

The latitude and longitude are first determined by (92). The criterion for determining whether the Sun is rising or setting at the place thus found is easily established by the value of θ, the hour angle of the point Z. If this angle lies between 180° and

FIGURE 4.



360°, which includes all points on the horizon, *NABS*, Fig. 4, the Sun is rising, and if between 0° and 180° which embraces all points on the horizon, *NA'B'S*, the Sun is setting. The sign of P' (102) will then determine whether the eclipse is beginning or ending. As no accurate observations can be made in the horizon, it will be sufficient to put both a' and $\zeta = 0$ and then we shall have

$$\sin (\Omega - E), \text{ negative, eclipse beginning}$$
$$\sin (\Omega - E), \text{ positive, eclipse ending}$$

But $$l \sin (\Omega - E) = l \sin \Omega \cos E - l \sin E \cos \Omega$$

and from (87) and (88) we find

$$l \sin \Omega = m \sin M - p \sin \gamma$$
$$l \cos \Omega = m \cos M - p \cos \gamma$$

Substituting these in the above we have

$$\begin{aligned} l \sin (\Omega - E) = & \quad m \sin M \sin E - p \sin \gamma \cos E \\ & - m \cos M \cos E + p \cos \gamma \sin E \\ = & \quad m \sin (M - E) - p \sin (\gamma - E) \end{aligned}$$

Therefore for all points in the rising or setting limits we have the following criteria:

$$m \sin (M - E) < p \sin (\gamma - E), \text{ eclipse beginning}$$
$$m \sin (M - E) > p \sin (\gamma - E), \text{ eclipse ending} \qquad (105)$$

where m, M, p and γ are already found by (88).

If the interior contacts exist (see Fig. 2*) the rising and setting limits form on the Earth's surface, two separate enclosed oval curves. See chart of total eclipse of June 16, 1890 as given in the *American Ephemeris*.

If T_1 and T_2 denote the times of beginning and ending on the Earth generally as determined by (93) and T'_1 and T'_2 the times of interior contact determined by (94), a series of points on the rising limit, that is, when the eclipse begins or ends at *sunrise*, will be found for a series of times assumed between T_1 and T'_1, and the points of the setting limit, that is when the eclipse begins or ends at *sunset*, for a series of times assumed between T'_2 and T_2. But when the interior contacts (94) do not exist, as in Fig. 4, the curve on which the eclipse begins at sunrise is continuous with that on which it begins at sunset and the curve of ending at sunrise is continuous with that of ending at sunset; the two curves meeting and forming a single closed curve extending throughout the whole eclipse and resembling a figure 8 much distorted. See chart of eclipse of January 21, 1898 as delineated in the *American Ephemeris*. A series of points on these curves will be found by assuming a series of dates between T_1 and T_2 equidistant say for every 10, 15, 20 or 30 minutes, according to the degree of accuracy desired.

To Find the Curve of Maximum Eclipse in the Horizon.

In this case we must have $\zeta = 0$ since the Sun is in the horizon, and if $\triangle$ denote the distance of the place from the axis of the shadow we have

$$\triangle \sin Q = x - \xi$$
$$\triangle \cos Q = y - \eta \qquad (106)$$

The amount of obscuration will of course depend upon the value of $l - \triangle$, and for the maximum eclipse we have the condition

$$\frac{dl}{dT} - \frac{d\triangle}{dT} = 0$$

Differentiating (106) we have

$$\frac{d\triangle}{dT} \sin Q + \triangle \cos Q \frac{dQ}{dT} = x' - \xi'$$

$$\frac{d\triangle}{dT} \cos Q - \triangle \sin Q \frac{dQ}{dT} = y' - \eta'$$

* This cut will be given later.

whence we get

$$(x' - \xi') \sin \varrho + (y' - \eta') \cos \varrho - l' = 0 \qquad (107)$$

since

$$\frac{d\triangle}{dT} = \frac{dl}{dT} = l'.$$

Equation (107) is identical with (98) when $\zeta = 0$ or when the place is in the horizon, therefore the condition which characterizes the maximum eclipse in the horizon is $P' = 0$, and this condition will evidently be satisfied when in (102) we put

$$\sin (\varrho - E) = 0$$

because $\zeta = 0$ and a' being always very small may be neglected. This condition gives us $\varrho = E$, or $\varrho = 180 + E$, therefore (106) becomes

$$\pm \triangle \sin E = x - \xi$$
$$\pm \triangle \cos E = y - \eta$$

and we also have

$$\xi^2 + \eta_1^2 = 1$$

The angle E is known at any time from its tabulated values computed by (101); x and y are also known for the same time, but $\triangle$, ξ and η are unknown.

Put $\quad m \sin M = x \qquad p \sin \gamma = \xi$
$\quad m \cos M = y \qquad p \cos \gamma = \eta$

then we have

$$\pm \triangle \sin E = m \sin M - p \sin \gamma$$
$$\pm \triangle \cos E = m \cos M - p \cos \gamma$$

whence we easily find

$$0 = m \sin (M - E) - p \sin (\gamma - E)$$
$$\pm \triangle = m \cos (M - E) - p \cos (\gamma - E)$$

Put $\qquad \psi = \gamma - E$

and $\qquad \sin \psi = \dfrac{m \sin (M - E)}{p}$

$$\pm \triangle = m \cos (M - E) - p \cos \psi \qquad (108)$$

The first of these determines ψ when p is known. As p always lies between ρ_1 and unity we may take for p the geometric mean between ρ_1 and unity, that is $\log p = \frac{1}{2} \log \rho_1$ which will be sufficient for all ordinary purposes, but if a more accurate value is

required we put $\gamma = \psi + E$ and then find p by (90) after which (108) must be re-computed, and the true value of ψ having been thus found and also of γ we have γ' by (91) and the latitude and longitude of each point on the curve by (92).

The first of (108) will give two values of ψ and therefore also two values of Δ, but in this particular case Δ can never be greater than l and therefore that value of ψ which would make $\Delta > l$ must be rejected, so that in general we have only one solution.

The limiting times between which the curve can exist, are known from the computation of the rising and setting limits, or they are the times when

$$m \sin (M - E) = p \sin (\gamma - E)$$

that is, the curve will be computed for those dates for which $m \sin (M - E)$ is less than l.

The degree of obscuration is the fraction of the Sun's apparent diameter covered by the Moon. When the place is on the edge of the umbra, the obscuration is total and the distance of the place from the *edge* of the penumbra is equal to the absolute difference of the radii of the penumbra and umbra or the algebraic sum of l and l_1, the latter being negative; but in any other case the distance of the place within the penumbra is $l - \Delta$, therefore if D denote the degree of obscuration as above defined we shall have when the place is in the horizon

$$D = \frac{l - \Delta}{l + l_1} \qquad (109)$$

In annular eclipses l_1 (the radius of the umbral penumbra) is essentially positive. When the place *is not* in the horizon we shall of course still have

$$D = \frac{L - \Delta}{L + L_1} \qquad (110)$$

where L and L_1 are the radii of the penumbra and umbra respectively on the *parallel* plane at the distance ζ from the fundamental plane.

Problems.

32. If π and π' denote the equatorial horizontal parallaxes of the Moon and Sun, f and f' the semi-angles of the penumbral and umbral cones and δ' the Sun's semi-diameter as seen from centre of the Earth, show that

$$t + t' = 2\delta'. \frac{\sin \pi}{\sin \pi - \sin \pi'}$$

33. Find the time the Sun's semi-diameter will take to cross the meridian, the declination being 23° 2′ and the semi-diameter 16′ 17″.

34. Given the Sun's declination (δ) and the interval between the times at which he is west and sets (h) to find the latitude of the place, refraction and the Sun's motion in declination being neglected.

35. Find the Sun's declination when he is at the same instant on the horizons of two places whose latitudes are 53° 23′ N., and 3° 12′ S., and longitudes 6° 20′ W., and 35° 10′ W., respectively.

36. If v and v' be the angular velocities of the Moon about the Earth and of the Earth about the Sun, both orbits supposed circular, and if α be the Moon's greatest elongation from the Earth as seen from the Sun, show that the times between the successive greatest elongations are alternately

$$\frac{\pi - 2\alpha}{v - v'} \text{ and } \frac{\pi + 2\alpha}{v - v'}.$$

EVENINGS WITH THE STARS.

MARY PROCTOR.

FOR POPULAR ASTRONOMY.

The Great Bear (*Ursa Major*) is now at its highest and nearly overhead, the Pointers indicating the Pole star (*a* of the Little Bear, *Ursa Minor*). Below the Little Bear, is Cepheus low down to the east of north, and Cassiopeia low down to the west of north. Perseus, the rescurer, is setting in the northwest, and above is the Camelopard. The Charioteer (*Auriga*) is nearing the northwest horizon, and is distinguished by the bright Capella. The Twins (*Gemini*) are also nearing the western horizon, and further west and higher we find the Crab (*Cancer*) below which is the Little Dog (*Canis Minor*). There are very few bright stars in the southwestern sky, *Alfard*, the heart of the Sea Serpent, *Hydra*, shining alone in a great blank space. Nearly overhead is *Leo*, the Lion, and *Coma Berenices* is close by the Hunting Dogs (*Canes Venatici*) being almost overhead, between *Coma* and the Great Bear.

Lower down in the south, we find the Crow (*Corvus*), and the Cup (*Crater*), resting on the back of the Serpent. Extending in the mid-heavens from the southeast to the south, between the Lion and the Crow, is *Virgo*, the Virgin. Low down in the south we find the head and body of the Centaur (*Centaurus*), supposed to typify the patriarchal Noah.

The Scorpion's heart has risen in the southeast and the stars of the Scales (*Libra*), glisten between the head of *Scorpio* and the Virgin's robes. Due east,

low down in *Ophiuchus*, the Serpent-Holder, the Serpent (*Serpeus*), he holds in his hand curving upward toward the Crown (*Corona Borealis*) its head being due west. Above it we see the bright Arcturus, in the constellation of the Herdsman (Boötes). In the northeast is *Hercules*, his head close to the head of the Serpent-Holder. Beneath his feet glows the Lyre (*Lyra*) with the brilliant Vega, and the Swan (*Cygnus*) has already half risen above the northeastern horizon. *Draco*, the Dragon, curves between the Great and Little Bear, towards Cepheus, and then curves its head, towards the heel of Herculus.

The Constellation Virgo.

This constellation occupies a considerable space in the heavens, and contains 411 stars. Its mean R. A. is $13^h\ 16^m$, Decl. $-2°\ 30'$. It is situated next east of Leo, and about midway between Coma Berenices on the north, and Corvus on the south. According to the ancient writers this constellation represents the virgin Astræa, the goddess of justice, who lived upon the Earth during the golden age, but being offended at the wickedness of man during the brazen and iron ages of the world, she returned to heaven, and was placed among the constellations of the zodiac, with a pair of scales, (*Libra*) in one hand and a sword in the other.

> "Faith flees, and piety in exile mourns;
> And *Justice*, here oppressed, to heaven returns."

Several bright stars are scattered about in this constellation, and may be traced out by the map:

> "Her lovely tresses glow with starry light;
> Stars ornament the bracelet on her hand;
> Her vest in ample fold, glitters with stars:
> Beneath her snowy feet they shine, her eyes
> Lighten, all glorious, with the heavenly rays,
> But *first* the star which crowns the golden sheaf."

The Leading Brilliant Spica Virginis.

Spica Virginis, is in the ear of corn, which in some of the olden star maps, is represented as being held in the left hand of the Virgin, in place of the sword. According to Egyptian mythology, Isis was said to have dropped a sheaf of corn as she fled from Typhon, who, as he continued to pursue her, scatterd it over the heavens. The Chinese call the zodiac, the *yellow road*, as resembling a path over which the ripened ears of corn are scattered. *Spica* may be easily recognized as it glows in solitary splendor, there being no visible star near it except one of the 4th magnitude, situated about 1° below it on the left. The position of this star in the heavens, has been determined with great exactness for the benefit of navigators. It is one of the stars from which the Moon's distance is measured for determining longitude at sea. Its situation is highly favorable for this purpose, as it lies within the Moon's path, and little more than 2° below the Earth's orbit. It comes to the meridian at 9 o'clock about the 28th of May, in that point of the heavens where the Sun is at noon, about the 20th of October. (Burritt's *Geography of the Heavens* p. 92-93.)

According to the spectroscopic observations made by Vogel, *Spica* revolves at a minimum rate of fifty-six miles a second, round the common centre of gravity of itself and an obscure companion. It is of a brilliant white hue, and of the first magnitude whilst the companion-star is of the 10th magnitude and of a bluish color. The movement of Spica, in the line of sight, is 14 English miles a

second, according to the photagraphic measurements made at Potsdam, whilst it is 17 English miles a second, according to the measurements visually made at Greenwich. (Table VI, appendix, p. 409. *System of the Stars.* By Agnes M. Clerke.)

Gamma Virginis.

Gamma Virginis is a fine double star, having a period of one hundred and eighty-five years. "In 1756 the components were 6½ seconds apart. They gradually approached till in 1836 they could not be separated by the largest telescopes. Since then they have been separating, and they are now 4½ seconds apart. They are nearly equal in magnitude being of the fourth magnitude, and both are pale yellow. (*Half Hours with the Telescope*, p. 55. By R. A. Proctor.) R. A. $12^h\ 36^m\ 5^s$; Decl. $-0°\ 50'.8$.

Other Brilliants in Virgo.

Theta (ϑ) Virginis, is a very pretty and interesting triple, the third star, which is nine times as far from the large one as its more obvious companion, will require a dark night and pretty sharp sight to see it well. There are very many beautiful and interesting pairs in Virgo, but as they are mostly below the sixth magnitude they are not marked in maps which only include the larger stars. There is a wonderful nebulous region in Virgo, bounded by the stars β, η, γ, δ, ε and β Leonis. Captain Noble, in his *Hours with a Three-Inch Telescope*, p. 98, gives the following advice: "If the student will arm his instrument with a power af about 40, and sweep slowly over that part of the sky contained within the curve drawn through these stars, he cannot fail to be astonished and pleased at the wealth of nebulous objects, and the pretty fields of stars that he will encounter. One of these curious objects is shaped like a boy's kite. A few are resolvable into stars, when seen through some of the enormous telescopes now comparatively common. Others are unmistakably gaseous."

Elliptical Nebula in Virgo.

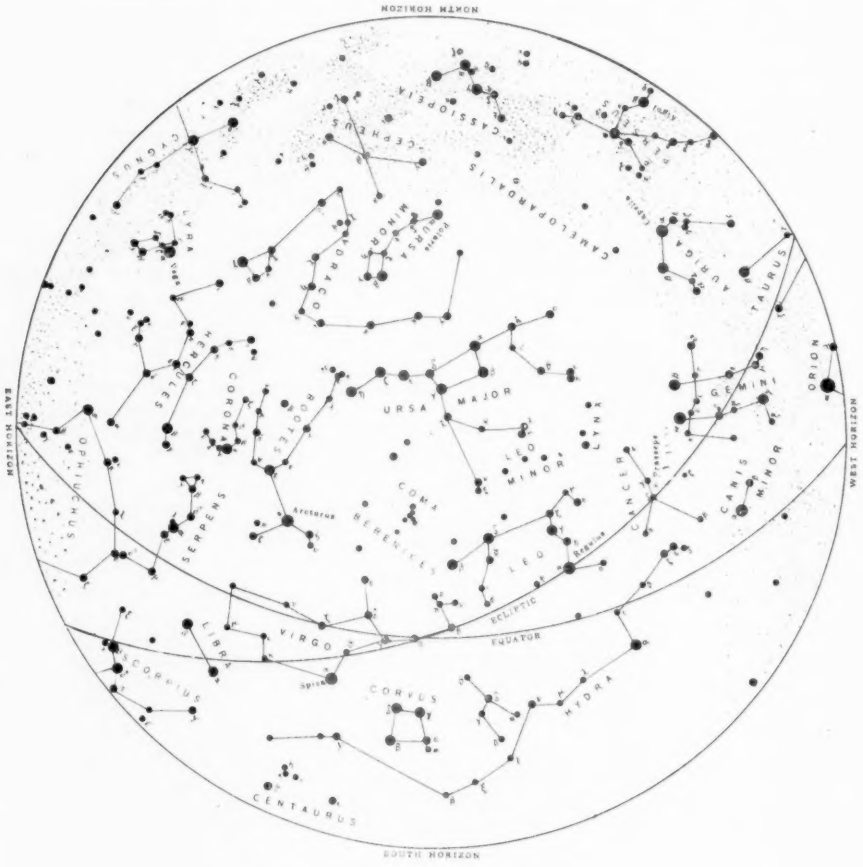
In the *Amateur Telescopist's Handbook*, by Frank M. Gibson, on page 162, reference is made as follows to the long elliptical nebula in Virgo. It is $7' \times 1½'$ in size. R. A. $12^h\ 26^m\ 26^s$; Decl. $+ 15°\ 1'.9$ Line from *a* to *d* and 12½° on 88 Messier (H 3049). "This is a wonderfully nebulous region and the diffused matter occupies an extensive space, in which several of the finest objects of Messier and the Herschels will readily be picked up by the keen observer, in extraordinary proximity. Reasoning upon the Herschelian principle, this may reverently be assumed as the thinnest or shallowest part of our firmament, and the vast laboratory of the segregating mechanism by which compression and insulation are ripened in the course of unfathomable ages. The theme, however imaginative is solemn and sublime." (Smyth's Celestial Cycle.)

Constellation of Bootes, the Herdsman.

Bootes, the Herdsman, or Bear-Driver as it is sometimes called, is represented in olden maps, by the figure of a huntsman in the attitude of running, grasping a club in his right hand, and holding up in his left the leash of his two greyhounds, Asterion and Chara, with which he seems to be pursuing the Great Bear round the pole of the heavens. He is thence called by the euphonious (?) name of Arctophylax, or the Bear-Driver. The constellation is situated between Corona Borealis, on the east, and Cor Caroli and the Greyhounds on the west. It contains 319 stars including one of the first magnitude, seven of the third, and ten of the fourth. Mean R. A. $14^h\ 30^m$; Decl. $+ 30°$.

Legend of the Bear Driver.

According to Grecian fable, Boötes was the son of Calisto, and named Arcas. Calisto incurring the wrath of Juno, was changed into a bear, and her son Arcas, who afterwards became a famous hunter, one day roused a bear in the chase, and



The Constellations at 9 p. m., May 1, 1897.

not knowing that it was his mother, was about to kill her, when Jupiter snatched them both up to heaven and placed them among the constellations.

The stars in this region of the skies seem to have attracted the admiration of many writers of antiquity. Claudian observes that:

> "Boötis, with his wain the north unfolds:
> The southern gate Orion holds."

And Aratus, who flourished nearly 800 years before Claudius, says:

"Behind, and seeming to urge on the Bear,
Arctophylax, on Earth Boötes named,
Sheds o'er the Arctic car his silver light."

Manilius thus speaks of this constellation:

"And next Bootis comes, whose ordered beams
Present a figure driving on his teams
Below his girdle, near his knees, he bears
The bright *Arcturus*, fairest of the stars."

Arcturus is mentioned by name in that beautiful passage in Job, where the Almighty answers "out of the whirlwind," and says:

"Canst thou the sky's benevolence restrain,
And cause the Pleiades to shine in vain?
Or, when Orion sparkles from his sphere,
Thaw the cold seasons and unbind the year?
Bid Mazzaroth, his station know,
And teach the bright *Arcturus* where to glow."
—*Young's Paraphrase.*

DESCRIPTION OF ARCTURUS.

Arcturus has a distant pale lilac companion and is a remarkable and interesting object. The companion star is of the 11th magnitude, and quite beyond the powers of a small telescope. When seen with an opera glass, Arcturus glows with a ruddy hue, but as it approaches the mid-heavens the color is rather of an orange tint. Garrett P. Serviss, tells us that "there is a scattered cluster of small stars surrounding it, forming an admirable spectacle with an opera glass on a clear night. To see these stars well, the glass should be slowly moved about. Many of them are hidden by the glare of Arcturus." (*Astronomy with an opera glass*, p. 54).

Schmidt considers that Arcturus has changed color of late years, and that whereas it was once very red, it is now a yellow star. On March 21st, 1852, Schmidt was amazed to perceive Arcturus without a trace of the strong color familiar to him in it, during eleven previous years. In comparison with its paleness, Capella seemed bright yellow, Mars and Betelgeuze glowed almost like fire. It was some years before the star resumed its original hue, and the reality in the change admitted by Argelander, was certified by the observations of Kaiser at Leyden. "Owing probably to the difference in color between Vega, Capella and Arcturus, photometricians have not been perfectly agreed as to the relative brilliancy of these objects. Some consider Vega, the most brilliant star in the northern heavens, while others assign the superiority to Capella. The majority, however, consider Arcturus the leading northern brilliant, and in the whole heavens place, three only before him, viz., Sirius, Canopus and *a* Centauri. Arcturus is remarkable in other respects. His proper motion is very considerable. "Assuming the accuracy of Dr. Elkin's nominal paradax of 0".018, its velocity across the line of sight alone must reach 372 miles a second, 380 being the utmost that our Sun can generate in a body reaching its surface from infinite space. Arcturus "moves palpably through the heavens" at the rate of 375 miles a second. It is plunged in depths of space unfathomable by any method yet brought into use. Its excessive remoteness enables us to recognize in it, perhaps the most stupendous sun within our imperfect knowledge, for although less lustrous than Canopus, it

is probably (judging from the character of its spectrum) much more massive proportionately to its light, while the rate of its movement can only be termed portentous." (System of the Stars, pp. 315, 345).

One might expect that so brilliant a star, must be comparatively near to us, but although it is approaching the Earth with an average speed of somewhere about 40 miles a second, yet we have only been able to roughly estimate its distance. It is probably three times as far from us as the small star 61 Cygni, and more than seven times as far from us as *Alpha Centauri*, so that a ray of light must be about thirty years in crossing the mighty abyss that separates us from this star.

Spectrum of Arcturus.

"The pale rose tint of the light of Arcturus, is accounted for by the slightness of absorptive effects in the red end of the spectrum, while numerous lines modify the yellow and green, and the violet rays are so feeble that, with an exposure *fifty times* that required for Sirius, Dr. Huggins obtained only an impression virtually bounded by F and H. This feebleness of chemical action may, however, be due, not to original deficiency of light, but to its stoppage in the vaporous envelope of the star. Of its spectral lines, seventy were determined by Huggins and Miller in 1863, seventy-two by Vogel ten years later, fifty-four being clearly traced by both observers to the radiations of the following nine substances: hydrogen, sodium, magnesium, calcium, iron, bismuth, tellurium, antimony and mercury. Beyond a doubtful indication of bismuth, there is no sign in the solar spectrum of the arrest of light by any of the last four elements, the high vapor densities of which it is important to note. If we were to consider only the visible spectrum of Arcturus, we should certainly suppose it to vary from the Sun in the same *direction* as Aldebaran—that is, to be farther removed than Capella from the Sirian stars. Its rays like those of Aldebaran, have a ruddy tinge, and are seen, when dispersed by the prism, to be powerfully stamped by metallic absorption. But the camera has a different story to tell. In the intensity of its ultra-violet as compared with the rest of its beams, Arcturus falls but little behind Sirius. The characters, however, are unlike what might have been expected. Up to the limits of visibility, the solar analogy is fairly well preserved, H and K, (the latter especially) being even more distended than in the Sun. But beyond, non-solar groups of strong lines appear; and among them six out of the nine typical rays of hydrogen." (System of the Stars, pp. 46-47)

Objects of Interest in Bootis.

Bootes is a very mine of objects of interest. We will begin with the star *Delta Bootis* which is a wide and unequal double, the smaller component being only of the ninth magnitude, the larger of the fourth. The small star is of a pale yellow color, the larger is pale blue.

Epsilon Bootis is an exceedingly beautiful and delicate object, known as Mirac, and on account of its extreme beauty it was called Pulcherrsima by Admiral Smyth. The components of this beautiful double star are of the third and seventh magnitudes, the primary orange, the secondary sea green. The distance separating them is about three seconds, perhaps more; it appears to be slowly increasing during the past ten or twelve years. Smyth assigns to this system a period of revolution of 980 years, but there can be little doubt that the true period is largely in access of this estimate. Observers in southern latitudes consider the color of the componeats are yellow and blue not orange and green as most of our observers have estimated them. (Half hours with the Telescope, pp. 60 61, by R. A. Proctor).

The star *Xi* Bootis, is also an interesting object, and a double star, the components being orange-yellow, and ruddy purple, and of the fourth and sixth magnitude. When this star was first observed by Herschel in 1780, the components were much closer than they are now, being separated by a distance of less than 3½ seconds. "Since that time the smaller component has traversed nearly a full quadrant, its distance, from its primary, first increasing, till in 1831 the stars were nearly 7½ seconds apart, and thence slowly diminishing so that at present the stars are less than 5 seconds apart. The period usually assigned to the revolution of this binary system is 117 years, and the period of peri-astral passage is said to be 1779. It appears, however, that the period should be about 108 years, the epoch of last peri-astral passage 1777 and the next peri-astral passage, therefore, 1885. The angular motion of the secondary round the primary is now rapidly increasing and the distance between the components is rapidly diminishing, so that in a few years a telescope will be required to separate the pair." (Half hours with the Telescope, p. 60). This star is 8½° from Arcturus on line to Beta Serpentis.

Not far from *Xi* Bootis is *Pi* (π) Bootis, a somewhat closer double, both the components being white, and their magnitudes 3½ and 6. This star is 7° from Arcturus on a line towards Alpha Serpentis.

44 Bootis is a remarkable and highly interesting binary with a period of about 261 years. A is of the fifth magnitude, and pale white. B is of the sixth magnitude and lucid gray. Sir W. Herschel calls this a miniature of Castor. It is situated 7½° from Beta Bootis, on line towards the north pole. (The Amateur Telescopist's Handbook, p. 104). The components were noted by Herschel as considerably unequal in 1781, they appeared to him perfectly matched in 1787. And it may be noted that they had in the interim passed periastron (this denotes the point at which a body revolving in orbit comes nearest its centre of motion). Struve observed June 15th, 1819, a difference between them of two magnitudes, which had sunk to half a magnitude in 1833. Argelander found them precisely equal June 6th, 1830; Dawes perceived, April 27th, 1841, a slight advantage on the side of the usually smaller star, while the superiority of its companion was recorded by M. Dunér at Lund as ranging, during the years 1869 to 1875, from 0.4 to 1.3 magnitudes. Since their changes are often simultaneous, though not always in the same direction, their combined variability has never been conspicuous. The stars of 44 Bootis complete their highly eccentric orbit in a period of 261 years. Their tints varying from yellow and sky-blue to white and dull gray, cannot be without influence upon their photographic magnitudes, which were determined at Paris in 1886 to be 5.3 and 6. Their joint light, though of the same spectroscopic quality, has then only one-twelfth the intensity of that of Gamma Virginis. (*System of the Stars*, p. 180).

Zeta Bootis must be looked for with the very highest power, of a three-inch telescope, but Captain Noble tells us, that "under the most favorable circumstances, the observer will only succeed in so far converting it into a slightly egg-shaped object as to show that it is not single." "The component stars, when photometrically measured at Harvard college in 1883, were of 4.4 and 4.8 magnitudes, but the order of their brightness has been at least three times reversed during a century of observation. Their period of observation must be of enormous length. From 1796 to 1841 they appeared fixed; then a very slow wheeling movement became perceptible, accompanied by a diminution of distance, and it now taxes the powers of the best telescopes to divide them. Their spectrum is of the Sirian type." (*System of the Stars*, p. 180).

Such are a few of the most interesting objects in this constellation. For an

account of others, reference can be made to "*Hours with a Three-inch Telescope*," "*Half Hours with a Telescope*," "*The Amateur Telescopist's Handbook*," "*Webb's Celestial Objects*," or Howe's "*Elements of Descriptive Astronomy*," Chapter XIV, on "The Constellations in Detail."

Constellation of Coma Berenices.

This is a beautiful cluster of small stars, situated mid-way between Cor Caroli on the northeast, and Denebola (Leo) on the southwest. Its mean R. A. is $12^h\ 30^m$; Decl. + 27°; and it contains 117 stars. The stars in this cluster are so closely grouped together, that they somewhat resemble the confused lustre of the stars in the Milky Way. Besides the stars already referred to, it contains a number of nebulæ. This constellation is on the meridian the 13th of May.

Legend of Coma Berenices.

Berenice was of royal descent, and a lady of great beauty, who married Ptolemy Soter, or Evergetes, one of the kings of Egypt, whom she loved with much tenderness. When he was going on a dangerous expedition against the Assyrians, she promised to dedicate her hair to the goddess of beauty, if he returned in safety. Some time after the victorious return of her husband Evergetes, the locks which agreeably to her oath, she had deposited in the temple of Venus disappeared. The king expressed great regret at the loss of what he so much prized, whereupon Conon, his astronomer, publicly reported that Jupiter had taken them from the temple and placed them among the stars.

> "There Berenice's locks first rose so bright,
> The heavens bespangling with disheveled light."

Conon, being sent for by the king, pointed out this constellation, saying, "There behold the locks of the queen." This group being among the unformed stars until that time, and not known as a constellation, the king was satisfied with the declaration of the astronomer, and the queen became reconciled to the partiality of the gods. (Burritt's *Geography of the Heavens*, p. 90).

> "Immortal Conon, blest with skill divine,
> Amid the sacred stars behold me shine;
> E'en me, the *beauteous hair*, that lately shed
> Refulgent beams from Berenice's head;
> The locks she fondly vowed with lifted arms,
> Imploring all the powers to save from harm
> Her dearer lord, when from his bride he flew,
> To wreck stern vengeance on the Assyrian crew."
>
> —(Translation from *Callimachus* by *Tyler*.)

Stars in this Constellation.

A little over one-third of the way from Arcturus to Beta Leonis, is the fifth magnitude star 42, which is a double star, having a period of somewhat less than twenty-six years, never diverging to a greater extent than about half a second, and occulting each other completely, twice in a revolution. They were discovered by Struve in 1827, and they have since presented an aspect of "indivisible singleness," (as Miss Clerke terms it), on five different occasions. The colors of the components are orange and pale blue, forming a charming contrast.

35 M is a globular cluster of minute stars, described as "a ball of innumerable worlds." It is just above and to the left of *a* Comæ. It requires a very powerful telescope to resolve this nebulous cluster into an immense mass of tiny stars.

24 Comæ is a beautiful double star, A being 5½ magnitude, and of orange hue, whilst B is of the 7th magnitude, is of an emerald tint and the colors are very brilliant. This star is to be found a little less than 13° from Beta Leonis on a line towards Arcturus.

THE MILKY WAY.

Special attention should be given this month, to the Milky Way, which can be traced from the southern horizon, near *Centaurus*, curving around the western and northern horizon, and vanishing in the northeast, in the constellation (*Cygnus*) of the Swan. It passes on its way (*Argo*) the Ship, (*Canis Minor*) the Little Dog, between (*Gemini*) the Twins and Orion *Taurus* and Auriga, Perseus, Cassiopeia, Cepheus and Cygnus In map V, of *Half Hours with the Stars*, by R. A. Proctor, its course can be clearly traced.

(N. B.—A more detailed account of the Milky Way will be given in the December number of this magazine, as a conclusion to the series of articles on "*Evenings with the Stars.*") M. P.

PLANET NOTES FOR MAY.

H. C. WILSON.

Mercury will be visible toward the north-west for a few days about an hour and a half after sunset. He is approaching the Sun and will be at inferior conjunction on the 20th.

Venus is now "morning star" having passed conjunction with the Sun on April 27. Early risers will see the planet toward the north-east, shining with the same brilliancy which has been so surprising to many during the past month. Venus and the Moon will be in conjunction on the morning of May 28.

Mars may yet be seen in the early evening toward the west; but is not at all conspicuous. He moves south-eastward from Gemini into the center of Cancer. Mars will be occulted by the Moon on the afternoon of May 7. From South America it may be possible to observe the occultation, but it will be with difficulty on account of the bright sunlight at the time.

Jupiter will be in excellent position during May, crossing the meridian at 7^h 30^m P. M on the 1st and at 5^h 39^m on the 31st, at an altitude of about 58°. Jupiter is in Leo a little way east from the star Regulus. Jupiter may be observed with advantage from 7 to 11 P. M. The best views are often obtained soon after sunset while the sky is yet bright.

Saturn will be at opposition on the 17th and so may be observed during the greater part of the night. Since, however, the planet is 17° south of the equator, its altitude is low and favorable for observations only when near the meridian. The observer will therefore get the best results in the hours near midnight. The rings of Saturn are now turned up at an angle of about 24° with the line of sight, so that their structure may be quite plainly seen and the divisions between them are readily seen by the inexperienced observer. Saturn is in Libra near the bright stars in the head of the Scorpion.

Uranus is near Saturn, a little over 2° toward the southwest from the latter, and comes to opposition on the same day.

Neptune is not in position favorable for observation.

Jupiter's Satellites for May.

Central Standard Time.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. III.

II. IV.

Configurations 9h for an Inverting Telescope.

Day.	West.	East.
1	·4 ·2 ·1 ○	·3●
2	·4 ○ ·2 1· ·3	
3	·1 ○ ·4 2· 3·	
4	2· ○1· 3· ·4	
5	·23· ○ ·1 ·4	
6	3· 1· ○ ·2 ·4	
7	·3 ○ 2· ·1 4·	
8	2· 1· ·3 ○ 4·	
9	○ 1· ·3 4· ·2●	
10	·1 ○ 2·4· 3·	
11	○4· 2· ○ 1· 3·	
12	4· ·2 3· ○ ·1●	
13	4· 3· 1· ○ ·2	
14	4· ·3 ○ ·1 2·	
15	4· 2· 1· ·3 ○	
16	·4 ·2○ ·1 ·3	
17	·4 ·1 ○ 2· 3·	
18	·4 2· ○ 1· 3·	
19	○3· ·2 ·4·1 ○	
20	○1· 3· ○ ·2 ·4	
21	·3 ○ ·1 2· 4·	
22	2· ·3 1· ○ ·4	
23	·2 ○ ·1·3 ·4	
24	·1 ○ ·2 3· 4·	
25	○2· ○ 1· 3· 4·	
26	·2 ·1 ○3· 4·	
27	3· ○1· ·2 4·	
28	·3 4· ○ 2· ·1●	
29	4· ·32· 1· ○	
30	4· ·2 ○ ·3·1	
31	4· 1· ○ ·2 ·3	

Phenomena of Jupiter's Satellites.

[In. denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse; Oc., occultation; Tr., transit of satellite; Sh., transit of shadow; * visible at Washington.]

Central Standard Time.

		h	m					h	m			
May	1	7	56 P. M.	III	Oc. Dis.	May	12	7	11 P. M.	I	Sh. In.
		11	31 "	III	Oc. Re.			8	14 "	I	Tr. Eg.
	2	12	56 A. M.	III	Ec. Dis.			9	30 "	I	Sh. Eg.
		4	16 "	III	Ec. Re.		16	10	2 "	II	Oc. Dis.
		10	21 P. M.	II	Ec. Re.		18	6	48 "	II	Sh. In.
	3	8	18 "	IV	Ec. Dis.			7	7 "	II	Tr. Eg.
	4	12	13 A. M.	I	Oc Dis.			9	38 "	II	Sh. Eg.
		12	21 "	IV	Ec. Re.		19	9	16 "	III	Tr. Eg.
		9	34 P. M.	I	Tr In.			10	29 "	I	Oc. Dis.
		10	47 "	I	Sh. In.			10	52 "	III	Sh. In.
		11	53 "	I	Tr. Eg.		20	7	49 "	I	Tr. In.
	5	1	6 A. M.	I	Sh. Eg.			9	6 "	I	Sh In.
		6	42 P. M.	I	Oc. Dis.			10	8 "	I	Tr. Eg.
		10	12 "	I	Ec. Re.			11	25 "	I	Sh. Eg.
	6	7	35 "	I	Sh. Eg.		21	8	31 "	I	Ec. Re.
	8	12	23 A. M.	II	Tr. In.		25	6	51 "	II	Tr. In.
		11	46 P. M.	III	Oc. Dis.			9	25 "	II	Sh. In.
	9	7	29 "	II	Oc Dis.			9	44 "	II	Tr. Eg.
	10	12	46 A. M.	II	Ec. Re.		26	9	39 "	III	Tr. In.
	11	7	1 P. M.	II	Sh. Eg.		27	7	14 "	II	Ec. Re.
		8	15 "	IV	Tr. Eg.			9	44 "	I	Tr. In.
		11	26 "	I	Tr. In.			11	1 "	I	Sh. In.
	12	12	42 A. M.	I	Sh. In.		28	6	54 "	I	Oc. Dis.
		6	53 P. M.	III	Sh. In.			9	42 "	IV	Sh. In.
		8	35 "	I	Oc. Dis.			10	26 "	I	Ec. Re.
		10	21 "	III	Sh Eg.		29	7	48 "	I	Sh. Eg.
	13	12	7 A. M.	I	Ec. Re.		30	8	12 "	III	Ec. Re.

Occultations Visible at Washington.

Date 1897.		Star's Name.	Magnitude.	IMMERSION. Washington M. T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
May	3	χ Tauri	5.7	7	17	108	8	15	265	0	58
	8	δ Cancri	4 0	4	58	78	6	0	344	1	2
	16	B.A.C. 5347.	6.0	7	6	143	7	51	254	0	45

The Moon.

		Phases.	Rises. (Local Time.) h	m		Sets. h	m	
May	1	New Moon	4	15	A. M.	7	28	P. M.
	9	First Quarter	11	5	"	1	22	A. M.
	16	Full Moon	8	18	P. M.	4	47	"
	23	Last Quarter	12	44	A. M.	11	58	"
	31	New Moon	3	53	"	8	25	P. M.

VARIABLE STARS.

J. A. PARKHURST.

Variable Star 7792 SS Cygni.—In No. 400 of the *Astronomical Journa* occurs an important note on the above named variable star by Paul S. Yendell. It is as follows:

"Since the publication in the A. J. 395 and 397, of J. A. Parkhurst's and my

observations of SS Cygni the star has been under observation by Mr. Sperra, who writes me under date of March 30, sufficient particulars of his work to confirm my suspicion entirely that the star's variation is identical in type with U Geminorum.

Mr. Sperra's observations show that the star continued constant at its normal brightness, of about 11^m.3 through February and until the morning of March 19. On the latter date he observed it as 11^m.0 and on the morning of the 21st as 7^m.7. Since the latter observation the star has decreased very rapidly, and at the date of Mr. Sperra's letter had returned to its normal faintness nearly. These observations confine the duration of the increase to two days, and also taken in connection with the observations published by Mr. Parkhurst and myself, indicate that the light curve is not constant at different maxima. The proof of the type of the variation is unequivocal. The interval between these two maxima is a little over sixty days as Sperra's observations seem to shut out the possibility of an intervening maximum."

Maxima and Minima of Long Period Variables.

1897 July.

MAXIMA.		Day	MAXIMA, Con't.		Day	MINIMA.		Day
112	R Andromedæ	6	5776	X Scorpii	19	434	S Piscium	25:
114	S Ceti	25	6062	RR Scorpii	6	513	R Piscium	22
243	U Cassiopeæ	11	6170	RW Scorpii	15:	782	R Arietis	31
1894	T Columbæ	10	6512	T Herculis	14	806	*o* Ceti	20
2583	L_2 Puppis	7	6794	R Lyræ	26	893	U Ceti	10:
2676	U Monocerotis	20	6900	W Aquilæ	10:	1577	R Tauri	16:
2857	U Puppis	27	7106	S Vulpeculæ	13	1623	T Camelop.	30:
3060	U Cancri	21	7252	W Capricorni	18	2213	η Geminorum	10
4315	R Comæ	22	7257	R Sagittæ	6	2676	U Monocerotis	2
4377	T Virginis	26	7455	U Capricorni	28	3994	S Leonis	24:
4492	Y Virginis	25	7468	T Aquarii	3	4896	T Centauri	27
4885	Z Centauri	26:	7733	Y Capricorni	10	5950	W Herculis	20
4940	W Hydræ	27	7754	W Cygni	3	6794	R Lyræ	3
5237	R Bootis	31	7813	R Gruis	20:	7045	R Cygni	4
5593	W Libræ	30	8597	V Ceti	9	8373	S Pegasi	27:

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

U CEPHEI.*

1897.

	d	h
June	1	14
	6	14
	11	13
	16	13
	21	13
	26	12

ALGOL.

June	7	20
	13	14
	30	19

S CANCRI.

June	13	9

S VELORUM.

June	13	14

δ LIBRAE.

1897.

	d	h
June	4	14
	6	22
	11	13
	13	21
	18	13
	20	21
	25	12
	27	20

U CORONAE.

June	6	19
	13	16
	20	14
	27	12

RS SAGITTARII.

June	2	13
	7	9
	9	19

RS Sagittarii Con.

1897.

	d	h
June	14	15
	19	11
	21	21
	26	17

U OPHIUCHI.

June	1	10
	3	22
	4	18
	5	14
	6	11
	8	23
	9	19
	10	15
	11	11
	14	20
	15	16
	16	12

U OPHIUCHI Con.

1897.

	d	h
June	17	8
	19	21
	20	17
	21	13
	22	9
	24	21
	25	18
	26	14
	27	10
	29	22
	30	18

W DELPHINI.

June	2	21
	7	16
	12	11
	26	21

The above ephemeris was computed for POPULAR ASTRONOMY directly from the elements given in Chandler's Third Catalogue. For the Algol type stars I have given all the minima which occur in the night hours in American and European longitudes, when the star is above the horizon. In the long period ephemeris all the stars are given whose periods are greater than 40 days. A colon after the date indicates doubt.

* *U Cephei.* In *Astronomical Journal*, No. 396, Dr. Chandler has given the following elements of the minima of this star, revised by the aid of the observations of the past four years:

1880, June $23^d\ 9^h\ 39^m.6 + 2^d\ 11^h\ 49^m\ 37^s.85\ E + 130^m \sin (0°.06\ E + 300°)$

These elements make the minima for June three quarters of an hour later than the times given above.

Anderson's new variable in Andromeda (see chart in March number page 528) has been assigned the notation 267 V Andromedæ.

Mr. W. E. Sperra has secured the following important maxima:

2815 U Geminorum, max. 1897, March 6.

7792 SS Cygni, Max. 1897, March 21 ±. The observed magnitudes of SS were:

	m
1897, Feb. 19 to March 16	11.4
" 19	11.0
" 21	8.0
" 22	8.2

These observations confirm the "U Geminorum" type of the stars variation, but do not confirm the announced 40 day period as 60 days or more have passed since the last maximum. An irregularity of period, if found, would make its resemblance to U Geminorum still more marked. The star deserves careful attention.

La Grange, Ga., 1897, March 31.

COMET NOTES.

Ephemris of Perrine's Comet *f* 1896.

This comet has been, during the past two months down toward the south polar regions of the sky, but is now returning to the north and will be above our horizon in the early evening after the 3d of May. Its theoretical brightness is about twice that at the time of discovery last November, but is rapidly declining and the comet will hardly emerge far enough from the twilight to be easily seen.

		R. A.			Decl.		log *r*	log Δ	Brightness.
		h	m	s	°	′			
May	3.5	9	28	30	− 43	36	0.2322	0.0378	2.3
	7.5		24	42	− 38	57			
	11.5		22	40	− 35	4	0.2551	0.1137	1.4
	15.5		21	47	− 31	50			
	19.5		21	41	− 29	8	0.2770	0.1838	0.9
	23.5		22	11	− 26	51			
	27.5		23	7	− 24	55	0.2981	0.2463	0.6
	31.5		24	23	− 23	17			
June	4.5		25	56	− 21	54	0.3183	0.3014	0.5
	8.5		27	40	− 20	44			
	12.5		20	34	− 19	44	0.3375	0.3497	0.3
	16.5	9	31	35	− 18	54			

Search Ephemeris for d'Arrest's Periodic Comet.

[From Bulletin Astronomique, January, 1897.]

		R. A. h m s	Decl. ° ′	Brightness.
May	1.5	22 51 25	− 1 31.6	0.23
	5.5	23 5 37	− 0 47.3	
	9.5	23 19 32	− 0 3.6	0.24
	13.5	23 33 38	+ 0 39.1	
	17.5	23 47 35	+ 1 20.5	0.25
	21.5	0 1 26	+ 2 0.4	
	25.5	0 15 10	+ 2 38.4	0.26
	29.5	0 28 46	+ 3 14.3	
June	2.5	0 42 13	+ 3 47.8	0.26

Comets of the Year 1896.

Approximate Elements.

Designation.	Perihelion.	Ω ° ′	i ° ′	q	ε
1896 I	1896 Jan. 31.84	208 54	155 45	0.5876	.....
II	Mar. 19.3	209 49	11 20	1.7382	0.5490
III	Apr. 17.65	178 16	55 34	0.5664	.....
IV	July 10.94	151 2	88 26	1.1425	.....
V	Oct. 25 99	192 6	11 33	1.4816	0.6574
VI	Nov. 4.16	18 1	6 4	1.9592	0.4695
VII	Nov. 24.60	246 35	13 39	1.1098	0.6772
1897 I	1897 Feb. 8.14	86 18	146 8	1.0623	.....

Other Data.

	Discoverer.	Date.	Synonym.	
1896 VII	Perrine	Feb. 15	*a* 1896	
II	Javelle	Sept. 26	*b* 1895	Faye's
III	Swift	Apr. 13	*b* 1896	
IV	Sperra	Aug. 31	*e* 1896	
V	Giacobini	Sept. 4	*d* 1896	Periodic
VI	Javille	June 20	*c* 1896	Brooks' 1889 V
VII	Perrine	Dec. 8	*g* 1896	Periodic
1897 I	Perrine	Nov. 2	*f* 1896	

GENERAL NOTES.

Honors for E. E. Barnard.—The leading article in this number will certainly interest all readers. Such honors for a scientific man, at any time of life, might well be coveted in any country. But Mr. Barnard has yet scarcely reached the prime of life; still he has received the highest honors that it is the power of critical and admiring scholarship of the world's most learned societies to bestow. Of course American astronomy in the bestowal of these medals has been duly recognized, and the home workers are newly encouraged and they will not be sparing in their enthusiastic recognition of what Mr. Barnard has done for astronomy in various lines of important original research. The article referred to gives a pretty full statement of the points of merit in Mr. Barnard's work which make the ground for the awards of the several medals bestowed. The illustrations are excellent for the method of reproduction chosen, and give a very true idea of the appearance of the medals themselves, the photographs being taken directly from them, and so finished and engraved as to produce a soft and

true effect. Less skill either in photograping them or engraving from the photographs would have produced a harshness and coarseness of result that would have been wholly undesirable. Our readers probably already know that the frontispiece, the gold medal of the Royal Astronomical Society, was presented this year for excellence of work in astronomical photography, for the discovery of the fifth satellite of Jupiter, and for general astronomical work, The The Arago Gold Medal from the Academy of Sciences of France was given in 1893 for the discovery of the fifth satellite of Jupiter. The Leland Gold Medal was presented to Mr. Barnard in 1892 for the discovery of the fifth satellite of Jupiter and for general astronomical work.

Dr. A. E. Brainard, of Burr's Mills, Jeff. Co. N. Y. has experience in the use of a 7⅛-inch telescope at his private Observatory which is already somewhat widely known. In a recent letter he reports an observation of Venus which can be best told in his own words, thongh they were not intended for publication. He says under date of April 22, "I have been studying Venus with our 7⅛-inch. I have thought that the unilluminated portion of the disk showed an outline. If so, (and the observation is most difficult) it can be seen here, in the early twilight, as soon as the planet becomes visible, in contrast with the pale yellowish tint of the sky. The disk has appeared to me of a slightly darker tint and with a suspicion of pale, evenescent grey color. Powers of 100 and 140 have been the best ones for the observation. My brother also has thought he could detect the globe outline very faintly on evenings of April 18, 20 and 21."

After giving this observation Dr. Brainard suggests that possibly this may not be a true observation and asks if he is misled by an optical illusion. It is more than probable that the observation represented truly what is to be seen. An appearance something like this is well attested by many observers from the time of Riccioli in 1643. Schröter, DeVico, Guthrie, Herschel, Green, Webb, Winnecke, Noble and others have spoken of the same thing under varying circumstances. At another time as we have more space a fuller account of this interesting matter will be given.

An Exhibition of Recent Designs of Astronomical Instruments was given March 31 at the works of Warner & Swasey in Cleveland. A very neat card of announcement was sent to many friends interested

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A Brashear 8½-inch Mirror and Flat mounted, 2 eye pieces mounted with rack and pinion is for sale at about half its original cost. It is said to be in good condition. Inquiries can be made of us.

Honor to Dr. Lewis Swift.—A description and photographs of a medal recently received by Dr. Lewis Swift, of the Lowe Observatory, Echo Mountain, California, from the Royal Astronomical Society, of England, have been received and will find place in our next number.

Daylight Observations of Venus.—In the Planet Notes for April, Vol. IV, p. 569, mention is made that Venus has been distinctly visible in full sun shine in the middle of the afternoon "during the past month." (March?).

Up to April 7th the planet has not been a difficult object when near the meridian even in the smoky atmosphere of a great city, San Francisco. I have

made almost daily observations since the 1st inst, with unaided eye, and during the last week have recorded no observation when she was not distinctly visible at least twice between noon and 2^h P. M. My notes are as follows: April 7, Venus obs. 1^h P. M.; April 8. 1^h 30^m P. M. (smoky); April 9, 1^h 30^m P. M. (light clouds); April 10 and 11, foggy, no obs.; April 12, 12^h 55^m P. M. (hazy, sky-glare bad); April 13, 1^h 29^m and 1^h 51^m P. M., very faint, (C. O. T. fails to find her); April 14, 1^h 02^m and 1^h 31^m P. M , brighter than yesterday (less smoke); April 15, 1^h 07^m and 1^h 25^m P. M., very faint and difficult to find. April 20, 1^h 35^m and 1^h 47^m P. M., which is the last time I am *certain* of seeing her.

A. H. BABCOCK.

1897, April 19.

Henry M. Paul of New Hampshire was made Professor of Mathematics in the United States Navy on April 7, 1897.

Death of Mrs. Lewis Swift.—It will be a surprise to the many friends of the astronomer, Dr. Lewis Swift, to learn of the recent death of his wife at their home, Echo Mountain, California, which occurred March 9, 1897. The home friends were not aware of the danger in her last illness which was short. Consequently the shock was doubly severe. Only a few days before the Dr. and Mrs. Swift had returned from a trip East to their home at Echo Mountain.

Kodaking the Stars.—We were interested to see in the Washington *Star* of April 25 a full account of what Harvard College Observatory is about to do. If the account is trustworthy, that industrious Observatory is soon to complete a new self-acting photographic telescope which will be of interest to observers and astronomy generally. Fuller description will be given later if the announcement is correct.

Ganymede in Transit.—On Tuesday evening, April 6 our class in astronomy was observing Neptune and noting its position in relation to stars in the same field for the purpose of detecting, by subsequent observation, Neptune's motion and thus identifying the planet for themselves.

At 8:15 the telescope was turned on Jupiter. A black spot near the northern edge of the northern equatorial belt proved to be Ganymede in transit. The satellite was closely observed till its egress at 10:47, central time. It appeared dark during the entire observation, except about ten minutes at the last when it was bright. For fifteen minutes before becoming bright it was so indistinct that one not knowing where to look would hardly have seen it with an 8-inch glass.

This is the first time I have seen any moon, except the fourth, appear dark in transit and as this transit was on a comparatively dark background I thought the fact of the Moon's dark complexion worthy of note. The contrast, however, between the dark, or dusky, complexion of the satellite and the inky blackness of the shadow, which appeared on the eastern limb of the planet nine minutes after the egress of the satellite, was very marked. W. A. CRUSINBERRY.

Drake University, Des Moines, April 8, 1897.

Stars Having Peculiar Spectra.—A list of stars having peculiar spectra is given in the annexed table. With four exceptions noted below they were all discovered by Mrs. Fleming in her regular examination of the Draper Memorial

photographs. The designation of the star, its approximate right ascension and declination for 1900, its catalogue magnitude, and a brief description of its photographic spectrum are given in the successive columns of the table. When the object is not a catalogue star its position as derived from a photograph, is given in the notes following the table:

Designation.	R. A. 1900.		Decl. 1900.		Magn.	Description.
	h	m	°	′		
.....	0	25.6	−46	58	.....	Types III Hydrogen lines bright. Variable.
.....	5	35.1	−69	52	.....	Gaseous Neb. Gal. long. 247° 08′, lat. −31° 43′
A.G.C. 6633	5	36.0	−34	8	2.5	Hβ bright, superposed on broad dark line. α Columbæ.
A.G.C. 9313	7	14.5	−24	47	4.6	Peculiar. 30 Can. Maj. Resembles ζ Puppis.
A.G.C. 10182	7	43.9	−25	42	5.3	Hβ bright. *o* Puppis.
−41°3911	8	10.8	−41	24	10	Hβ, Hγ, Hδ and Hζ bright. Resembles η Carinæ.
A.G.C. 12465	9	4.8	−70	8	5.2	Hβ bright, superposed on broad dark line. E Carinæ
A.G.C. 17542	12	48.8	−56	37	5.5	Hβ bright. Companion to μ Crucis.
.....	13	31.1	−55	58	.....	Peculiar. Variable.
A.G.C. 19273	14	8.0	−56	37	5.6	Hβ bright.
.....	16	21.1	−43	26	.....	Type IV.
A.G.C. 22610	16	39.2	−46	54	7.4	Bright band wave length about 4700
−36°11341	17	7.0	−37	0	9.1	Gaseous Neb. Gal. long. 317° 13′, lat. −0° 45′.
.....	17	11.6	−45	52	.....	Type IV.
−7°4689	18	39.1	−7	12	8.2	Hβ bright.
−7°5141	19	55.7	−7	39	9.8	Type IV
.....	20	8.5	−44	43	.....	Peculiar. Variable.
A.G.C. 29191	21	11.5	−39	15	7.3	Peculiar.
A.G.C. 31272	22	55.0	−23	4	8	Peculiar.

The position of the first star is R. A. = 0h 24m 23s.9, Decl. − 47° 6′ 3″ (1875) Dr. DeLisle Stewart,* at Arequipa, called attention to the spectrum of this star on a plate taken with the Bruce 24 inch telescope, adding the remark "bright lines (hydrogen?)." On examination by Mrs. Fleming it proved to be variable having a spectrum of the type characteristic of such stars.

The position of the second object which is in the larger Magellanic Cloud is R. A. = 5h 35m20s.0, Decl. − 69° 52′ 51″ (1875).

The bright band in ζ Puppis having wave length 4688 is dark in the spectrum of 30 Canis Majoris The spectrum, like that of the adjacent star, 29 Canis Majoris, was found by the writer to contain the additional hydrogen lines having wave lengths 3925, 4027, 4202 and 4544.

The bright line in the spectrum of *o* Puppis was found independently by Dr. Stewart.

The position of the ninth star is R. A. = 13h 29m 32s.3, Decl. − 55° 50′ 10″ (1875). The spectrum of this star may resemble that of ζ Puppis, since it contains two bright lines which may coincide with the lines having wave lengths 4633 and 4688 in the spectrum of that star. ζ Puppis, 29 Canis Majoris 30 Canis Majoris and this star may form a subdivision of Type V. All of these stars are near the central line of the Milky Way.

* Dr. Stewart's astronomical work began at Goodsell Observatory of Carleton College, Northfield, Minn.

The bright line in the spectrum of A. G. C. 19273 was found by Miss A. J. Cannon.

The position of the eleventh star is R. A. = $16^h\ 19^m\ 15^s.9$, Decl. $-43°\ 22'\ 49''$ (1875).

The thirteenth object $-36°$ 11341, is N. G. C. 6302.

The position of the fourteenth star is R. A. = $17^h\ 9^m\ 46^s.1$, Decl. $-45°\ 49'\ 44''$ (1875).

The position of the seventeenth star is R. A. = $20^h\ 6^m\ 45^s.2$, Decl. $-44°\ 46'\ 59''$ (1875). Dr. Stewart noted "bright line star (faint)" on a Bruce photograph. An examination by Mrs. Fleming shows that the star is variable and that the spectrum is peculiar.

Distribution of Stars in Clusters – Professor Bailey has recently made a count of the stars in the vicinity of several clusters. An enlargment was made of a photograph of the Pleiades taken with the Bruce telescope and having an exposure of six hours. A region 2° square, with η Tauri (Alcyone) in the centre was divided into 144 smaller squares, each 10′ on a side. The stars in each of these squares were then counted. The total number thus found was 3972, an average of 28 in each square. The 42 squares including the brighter stars in the group contain 1012 stars, an average of 24 per square. It therefore appears that the total number of stars in the region of the Pleiades is actually less than that in adjacent portions of the sky, of equal area, and it is much less than the corresponding number in many parts of the Milky Way. The Pleiades must, therefore, be regarded, first as a group consisting of comparatively bright stars, secondly, if we omit the bright stars, the number of faint stars will be much less than in the adjacent portions of the sky. This absorption of the faint stars is probably due to the nebulosity surrounding this group. A similar absence of faint stars is noticeable near other diffused nebulæ, for example, that surrounding N. G. C. 6726-7. This condition would be explained if we assume that stars have not yet been formed by the condensation of this portion of the nebula or that the latter is less distant and slightly opaque.

A similar count was made of ten regions 5′ square, in the vicinity of η Carinæ. The plate used was taken with the 24-inch Bruce telescope, and had an exposure of four hours. From this count it appears that in a region 5° square, and represented in Plate 2 described in Circular No. 15, the total number of stars was about 250,000, while the number contained on the entire plate exceeded 400,000. EDWARD C. PICKERING.

Harvard College Observatory,
Circular No. 17, March 30, 1897.

Air Ships.—An unusual amount of interest has been manifested during the last sixty days, in what most people are pleased to call "air ships," or remarkable sights in the sky at night, or meteors sometimes. Many queries have come to us during the last thirty days, seeking information concerning the strange celestial visitors. We have not had the pleasure of seeing anything unusual in the evening skies recently, though we are aware that many other observers have seen such moving objects at night, not always easy of explanation for everyone at the time.

From all information received it would seem that some have been misled by the planet Venus from its position, in the early evening, in the western sky, especially if the haze or light clouds are near the planet. From other descriptions

it is probable that some clever amateurs have been very busy of late in experimenting with various shapes of the toy balloon. It is evident that these little "whale backs" are provided with various colored lights which naturally serve to awaken much curiosity when they are near enough to be seen well, because of the changes in hue that prevail at different times. It is our opinion that most of these "strange" views lately seen, are clever artifices sufficiently obscure as to the starting point to add to the wonder of sight simply because the origin is unknown. At all events these strange visitors are harmless, and in no wise to be feared on any account.

Observations of the Maximum of *o* Ceti (Mira) in 1896-7.—The following observations of this remarkable variable, though interrupted by several intervals of cloudy weather, may supply a few missing links in the gradations of change perhaps more continuously observed elsewhere:

Sept.	25, midnight.	Distinctly brighter than companion star, but not more than one magnitude brighter. In the light of the gibbous Moon they seemed alike in tint.
"	26th 1:30 A. M.	Do.
Oct.	11th 10:00 P. M.	More than one magnitude brighter than companion.
"	20th, 27th	Do. Noticeably reddish.
"	28th	Discernable in an opera glass.
Nov.	11th	Not equal to 70 Ceti to the north, but equal to 71 to the east.
"	12th, 13th	Do.
"	24th	Visible to naked eye. Equal to 70 brighter than 71.
"	25th	Do.
"	28th	Brighter than 66.
"	29th	Do.
Dec.	2d	As bright as ξ in the cord of Pisces.
"	5th	Brighter than ξ Piscium.
"	6th, 7th	Do.
"	8th	Somewhat brighter than ξ Piscium.
"	19th	Equal to Delta Ceti.
"	21st	Brighter than Delta but not as bright as Gamma Ceti.
"	24th	Do
"	30th	Of the same brightness as Delta Ceti.
"	31st	Do.
Jan.	1st, 2d, 5th, 6th, 7th.	Equal to Delta.
"	8th	Less than Delta.
"	9th	Brighter than Delta. Perhaps this is the effect of moonlight.
"	14th	Of the same brightness as Delta.
"	15th	Fainter than Delta though the Moon is nearly full.
"	17th, 22d, 23d, 25th.	Fainter than Delta.
Feb.	1st	Fainter than Delta.
"	7th	About $\frac{1}{2}$ magnitude fainter than Delta.
"	21st	Equal in brightness to ξ Pisium. Brighter than 69 and 70 Ceti.
"	22d	Do.
"	23d	Not as bright as ξ Piscium.
"	24th	Brighter than 66, 69 and 70 Ceti.
"	25th, 26th, 27th,	Do.
March	1st, 2d, 4th, 5th, 8th, 9th and 10th.	No noticeable change.
"	11th and 12th.	Doubtful
"	18th	Fainter than 70.
"	20th	Equal to 66 in opera glass and brighter than 71.

After this date no satisfactory comparisons could be made.

ROSE O'HALLORAN.

San Francisco, April 10th, 1897.

Solutions of Problems 28, 29 and 31.—Mr. Thomas Lindsay of Toronto, Ontario, has solved problems 28, 29 and 31.

Errata.—In the Paper on Eclipses March, 1897, page 503, line 20, for $\zeta = 1$ read $\rho = 1$; line 33, for AD $= \frac{b^2}{a^2} x$ read ND $= \frac{b^2}{a^2} x$. Page 513, line 10, for $T = T_0 \pm \tau$ read $T = T_0 + \tau$.

BOOK NOTICE.

Elements of Descriptive Astronomy, by H. A. Howe, Professor of Astronomy in the University of Denver and Director of the Chamberlain Observatory. Messrs. Silver, Burdett & Company, New York, Boston and Chicago, 1897, pp. 340.

This new book takes the name, *Elements of Descriptive Astronomy*, which is quite true of its contents. On the whole it is a plain, direct setting forth of the chief things about astronomy, as now known, so that a scholar of limited knowledge in the associated branches of science will read it with comparative ease, sustained interest and personal profit. The frontispiece is a full page, colored plate representing twelve different kinds of spectra, including the different types which the heavenly bodies present, and in respect to which important scientific data now relate.

The early chapters have to do with a general survey of the heavens, apparent daily motions of the stars, the telescope, the Sun, the Earth, celestial measurements, the Moon and eclipses, motions of the planets and the study of the planets in order particularly. The later chapters deal with comets and meteors, the fixed stars, the nebulæ and the constellations in detail, followed by eight appendices, a full index and a set of useful star maps.

This book is evidently an independent attempt of a scholarly and an enthusiastic astronomer to bring into reasonable compass the essential elements of descriptive astronomy for the use of colleges and secondary schools.

The publishers have apparently spared no pains to do their part of the work tastefully and well. This is saying not a little when one knows, as the writer does, what it costs to make a book, even in this time of low prices in everything. The one hundred and ninety-five illustrations present some new features, especially the generally good small cut likenesses of eminent astronomers of earlier and later times, who have been, in some prominent way, connected with the development of astronomy in the times in which they lived.

The plan of the text is after the best modern way, with numbered paragraph themes, whose titles are set in heavy faced type for ease of reference and ready designation of theme which always well meets the needs of both teacher and student. At the end of each chapter will be found from one to four pages of exercises, so-called, interspersed with helpful remarks. The exercises are mainly in the form of well-chosen questions which the student is expected to answer orally, or in way best suited to the topic under consideration. The plan is the same as that used by Miss Mary E. Byrd in her excellent little book known as "Questions on the Sky," and the other soon to be published under the title of Laboratory Methods in Elementary Astronomy. A live teacher can make telling use of such matter with classes of any grade.

In the earlier part of the book we find a page table giving the pronunciations of the names of the constellations. In appendix I is a table of the pronunciation of over fifty of those hard star names which so much trouble the teachers of secondary schools as well as professors in college sometimes. The name of the star α Orionis, *Betelgueuse*, which is the most serious and uncertain one of all the Arabic words to pronounce was at once looked for in this table. The spelling of the pronunciation given is Bĕ'-tel-jŭz, accented in the first syllable. The e in the first and u in the last syllable are both sounded long. We can but wish that Professor Howe had given the authority for these pronunciations.

The appendices giving the land marks in the history of astronomy, topics for essays, queries for reviews and examinations and lists of reference books are very valuable helps.